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A STUDY OF THE PERFORMANCE OF DOWPAC HCS WHEN APPLIED TO THE TREATMENT OF SETTLED SEWAGE. THE CITY OF BATTLE CREEK, MICHIGAN

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A STUDY OF THE PERFORMANCE OF DOWPAC HCS WHEN APPLIED TO THE TREATMENT OF SETTLED SEWAGE FROM THE CITY OF BATTLE CREEK, MICHIGAN

A Report of the Project Steering Committee, written by:

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United States Public Health Service

and

Edward H. Bryan, Sanitary Engineer,
The Dow Chemical Company

With a Statistical Analysis by: K. A. Busch, Analytical Statistician,
United States Public Health Service

June, 1958

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C. N. Shadix - Chemist
C. R. Hirth - Chemist

City of Battle Creek

Dean Sheriff - Chemist
Al Lemon - Chemist
William Shiarla - Sampler

The Upjohn Company, Kalamazoo, Michigan

Ward Holz - Chemist

The tower was designed and construction was supervised by Jones, Henry, and Williams Engineers, the City of Battle Creek and The Dow Chemical Company.

Maintenance by the City of Battle Creek was under the direction of Kenneth E. Garvey, Superintendent of Water and Sewer, City of Battle Creek.

Regular Battle Creek sewage treatment plant operating personnel under direction of John Larson, Chief Operator, assisted in sample collection.

Weather data were supplied by the City of Battle Creek Flood Warning Station.

This report was compiled and data were analyzed by A. E. Becher, Jr., U. S. Public Health Service and E. H. Bryan, The Dow Chemical Company.

Statistical Treatment of data was under the direction of K. A. Busch, U. S. Public Health Service.

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SUMMARY

A cooperative project to study the performance of Dowpac HCS, a gas-liquid contact tower packing, as a biological slime attachment surface for secondary treatment of sewage at the City of Battle Creek, Michigan, was initiated in December, 1955. The City of Battle Creek, Jones, Henry and Williams (Consulting Sanitary Engineers), Michigan Department of Health, State of Michigan Water Resources Commission, Kellogg Company, General Foods Corporation, United States Public Health Service and The Dow Chemical Company cooperated in this study.

The Dowpac HCS component of the pilot plant structure consisted of a square module (37-1/2 inches by 37-1/2 inches), 42-feet deep. The packing was interrupted at three positions, 10-1/2 feet apart, to provide access for intermediate-section observation and sampling. Effluent from one of two primary sedimentation tanks at the City of Battle Creek Sewage Treatment Plant was applied to the "tower" by means of a rotary, 4-arm distributor, 36 inches in diameter. A manually-cleaned, pilot scale, final sedimentation tank was provided. Its primary purpose was to concentrate sludge generated by the pilot plant for contemplated further study.

The pilot plant was operated at five different hydraulic application rates. The study was preceded by an investigation of the hourly variation in waste strength concentration over a period of seven days to assist in selecting representative sampling intervals. During operation of the pilot plant, meetings were held by the Project Steering Committee, consisting of representatives of all cooperating organizations, to discuss various aspects of the study.

The report contains a summary of data obtained and calculations based upon the data. An equation was developed from the data relating performance as a function of depth and the hydraulic application rate. From the available data, it was not possible to distinguish a relationship between performance and organic application rate. Indications were that within the narrow range of organic application rates studied, variations resulting from daily fluctuations in waste strength, efficiency was independent of organic loading.

The pilot plant was in operation continuously from January 13, 1956 through June 27, 1956. Data were not taken between April 30 and June 10. Analyses included determination of 5-day Biochemical Oxygen Demand, Chemical Oxygen Demand (Dichromate-reflux procedure using silver sulfate as a catalyst), Suspended Solids, and Temperature.

The report was compiled by Mr. A. E. Becher, Sanitary Engineer, United States Public Health Service, and Mr. Edward H. Bryan, Sanitary Engineer, The Dow Chemical Company. The data were statistically analyzed by Mr. K. A. Busch, Analytical Statistician, United States Public Health Service.

INTRODUCTION

In December 1955, the City of Battle Creek while investigating techniques for secondary treatment of city sewage directed inquiries to The Dow Chemical Company concerning experimental work in progress dealing with the use of plastic tower packings for treatment of wastes. Dowpac* HCS one of several packing shapes under study, seemed particularly well suited to provide attachment surfaces for biologically active films. Wastes passing in relatively thin films over these surfaces simultaneously in contact with air could absorb oxygen to replace that used by respiratory activity of organisms in the biologically active film. Although some data were available relative to the performance of Dowpac HCS when used to treat domestic sewage, it was considered desirable to obtain quantitative performance information under conditions as similar as possible to those under which a full scale unit at Battle Creek would operate. It was decided to investigate the possibility of obtaining design data by operation of a pilot plant at Battle Creek, Michigan.

Preliminary discussions were held with personnel from organizations having a direct or potentially direct interest in a pilot study. These included: The City of Battle Creek, The Dow Chemical Company, General Foods Corporation, Kellogg Company, Michigan Department of Health, and the State of Michigan Water Resources Commission. It was generally agreed that a study should be undertaken. The mechanics of the contemplated project were considered. It was apparent that qualified technical personnel for temporary assignment to this project were not available from these organizations. In view of the possibly fundamental importance of the contemplated study, the Michigan Health Department requested assistance from the United States Public Health Service. Tentative approval of technical assistance was given by the Service.

PROJECT ORGANIZATION AND ACTIVITIES OF THE STEERING COMMITTEE

A meeting to discuss the contemplated project was held on January 4, 1956. In attendance at this meeting were the following:

A. E. Becher, Jr. - Sanitary Engineer, U. S. Public Health Service, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio

Edward H. Bryan - Sanitary Engineer, The Dow Chemical Company, Midland, Michigan

Arthur N. Corcoran - State of Michigan Water Resources Commission, Lansing, Michigan

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*Trademark of The Dow Chemical Company

L. E. Crandall - Assistant Director of Public Works and Assistant City Engineer, City of Battle Creek, Michigan

Kenneth E. Garvey - Superintendent of Water and Sewer, Battle Creek, Michigan

W. C. Goggin - Manager, Plastics Technical Service, The Dow Chemical Company, Midland, Michigan

Robert E. McIntosh - Director of Public Works and City Engineer, Battle Creek, Michigan

W. Allan Moore - Chemist, U. S. Public Health Service, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio

Donald M. Pierce - Chief Sewerage and Sewage Treatment, Michigan Department of Health, Lansing, Michigan

W. W. Towne - Chief, Water Pollution Control, U. S. Public Health Service, Cincinnati, Ohio

L. G. Williams - Jones, Henry and Williams, Consulting Engineers, Toledo, Ohio

Subject matter discussed included:

1. Organization of a committee to guide the progress of the study.

2. Initial experimental work including personnel requirements and additional laboratory facilities.

3. Financial support of the project.

A committee was organized and designated as the "Steering Committee" consisting of the following men:*

Robert McIntosh, Chairman, City of Battle Creek
E. H. Bryan, The Dow Chemical Company
A. N. Corcoran, Michigan Water Resources Commission
D. M. Pierce, Michigan Department of Health
W. W. Towne, U. S. Public Health Service
L. G. Williams, Jones, Henry and Williams, Consulting Engineers

*Representatives from the Kellogg Company and General Foods Corp. were not present. A representative from each company would be requested to participate on the Committee.

The project was placed under the immediate supervision of A. E. Becher, Jr., U. S. Public Health Service. A tentative date for the next committee meeting was selected. Mr. Crandall was selected by Mr. McIntosh to represent the City of Battle Creek during his temporary absence.

Initial contemplated experimental work was discussed including a survey to determine waste strength characteristics and their hourly variation. This would assist the committee in organization of the project and would be of value to the city and their consultant.

Financial matters were also considered. Although personnel were available for temporary assignment to this project from the Public Health Service, it was necessary to set up a fund from which their per diem expenses would be reimbursed to the Service by the City of Battle Creek. In view of their mutual interest in such a project, the City of Battle Creek, Kellogg Company, General Foods Corporation, and The Dow Chemical Company each contributed $2500 to a fund which would be administered by the City of Battle Creek. The purpose of the fund was to proportionately assess cooperating units for construction of the pilot plant, per diem expenses of Public Health Service personnel, and incidental expenses associated with the project. The Dow Chemical Company offered to furnish specialized laboratory equipment, chemicals, and supplies in addition to the required quantity of Dowpac HCS, pumps, control and metering equipment for the proposed unit. In view of the critical timing to Battle Creek, construction of the pilot plant structure was already underway. The meeting was concluded by a visit to the treatment plant for the purpose of inspecting construction progress and to survey the available laboratory facilities.

On January 13, 1956, operation of the pilot plant was started at approximately 11:00 A.M. The initial hydraulic application rate of 33.1 gpm was selected as a rate suitable for activation of the tower and for the initial experimental setting. A meeting on January 16 (A. E. Becher, W. A. Moore, and E. H. Bryan) was held to discuss installation of apparatus for determination of oxygen demand, to review progress on installation of laboratory equipment, and to further discuss initial phases of the study. Examination of the Dowpac HCS surfaces indicated that biological film formation had begun.

Sampling began on January 31 to establish the relationship between waste strength and the time of day. Data were available to indicate this pattern for the second meeting of the Steering Committee which was held on February 2, 1956. Agreement upon the proper sampling schedule to obtain representative performance data was readily reached. Some question remained as to the variation in the pattern over a longer time interval. One of the decisions reached at this meeting was to continue the strength-volume-time study to obtain a 7-day pattern. Tower sampling was scheduled to begin on February 3. One important initial objective was to attempt establishing a correlation between 5-day Biochemical Oxygen Demand and the Chemical Oxygen Demand determined by the dichromate-reflux method. Such correlation for the Battle Creek waste would allow discontinuance of the 5-day BOD technique for a large proportion of samples. The extensive sampling and concomittant laboratory analytical work made additional personnel essential. The committee decided to investigate several possible sources of additional technical manpower.

The financial picture was reviewed. Of the original fund, approximately $6100 had been expended for tower construction, settling tank fabrication, the supplementary BOD incubator and incidental expenses. It was estimated that the remaining fund would allow operation of the pilot plant for at least two months. The next meeting date of the Committee was set for February 10. Inspection of the pilot plant which had been in continuous operation for three weeks concluded the February 2 meeting.

The Committee met on February 10. In attendance were Messrs. McIntosh, Williams, Pierce, Corcoran, Crandall, Bryan, Becher, Neal Fitzsimmons and W. Kitchen representing the Kellogg Company, and J. Graham representing General Foods Corporation. Mr. McIntosh announced that additional technical assistance had been made available by the Upjohn Company of Kalamazoo, Michigan for the critical manpower phase of the project. Mr. Becher reviewed progress during the preceding week. From the data it was again apparent that sampling could be scheduled to fit into normal operating schedules at the plant. Application at the 33.1 gpm rate was resulting in approximately 35% efficiency. It was not evident that equilibrium had been attained therefore it was decided to maintain this application rate until stability was evident.

There was extensive discussion of the manually cleaned settling tank as a component of the pilot treatment plant; that is, basing performance of the tower upon the effluent of the tank. The original intent of the settling basin was to accumulate solids for a study of sludge handling problems. In view of the desire to vary the hydraulic application rate, the fixed hydraulic characteristics of the tank would introduce a variable into the over-all performance of the system. Adjustment of inlet and outlet conditions for similitude not only with the variation of flow but with full scale design also seemed impracticable. Although it was agreed that parallel sampling of the tank effluent and a laboratory settled tower effluent would be desirable, agreement was not reached as to the method of evaluating performance. Modification of the settling tank by installation of an influent baffle to improve its performance was mutually agreeable. Discharge of toxic materials to the sewers was thought to be well under control. Previous history had indicated this to be a source of difficulty in operation of the digester. A tentative date for the next meeting of the Committee was selected. After adjournment, the pilot installation was inspected. It was observed that excessive sludge accumulation in the settling tank was obviously affecting its performance. The tank was drained and cleaned. A daily sludge scraping routine was instituted following fabrication of a scraping tool.

The next meeting of the Committee was held on March 1, 1956. Messrs. McIntosh, Williams, Pierce, Bryan, Corcoran, Crandall, Graham, Towne, Becher, and Kitchen were present. Mr. B. B. Berger, Mr. James B. Coulter, and Mr. W. A. Moore, U. S. Public Health Service; and Mr. S. Paradiso of the Upjohn Company were also in attendance of this meeting. A discussion of data taken during the preceding interval was the principal item of business. Earlier, it had been generally agreed that experimental work would not interfere with procedure by the consultant toward design of facilities which were not directly related to the oxidation process selected. This was reaffirmed and progress was reported on such plans. The consultant was requested to make a preliminary calculation of the relative economy of a Dowpac unit versus conventional activated sludge which would be used as a basis for judging the value to the city of continuing the experimental work. An additional pump was to be installed to evaluate the effect of recirculation. Finances were reviewed and the fund was thought adequate to meet expenses through the next meeting of the Committee.

The next meeting was held on April 10, 1956. Mr. Williams presented the following summary of an economic analysis to the Committee:

Plant Type	Investment	Annual Cost		
		Power	Fixed Charge	Total
Activated Sludge	$1,215,000	$39,000	$ 72,900	$111,900
Dowpac HCS w/o Recirculation	1,899,000	16,950	114,000	130,950
Dowpac HCS, 1:1 Recirculation	1,274,000	35,200	76,400	111,600

On the basis of relative cost, the consultant's opinion was that conventional trickling filtration was completely out of consideration. Possibly significant items which were not considered because of the uncertainty involved were:

1. Improvement in performance with summer operating temperatures.

2. Simplified maintenance and operational costs exclusive of power for the Dowpac HCS design.

3. Sludge handling facilities thought to be somewhat more complex and costly for the activated sludge system.

4. Possible omission of additional primary sedimentation facilities for a Dowpac HCS design.

5. Possible combination of "roughing" treatment on a Dowpac HCS unit followed by activated sludge.

6. Unusual foundation difficulties which could be of significance relative to placement of the installation on the available site in Battle Creek.

In view of the economic analysis provided by their consultant, the city expressed no further direct interest in continuation of the project. Continued operation would however, be allowed by the city in order that uncertainties enumerated above could be more completely resolved. Continued operation to obtain additional data was thought desirable by the Public Health Service, The State of Michigan Department of Health, and The Dow Chemical Company. The decision was reached to continue operation of the unit on a maintenance basis until such time as agreement could be reached on the nature of further studies.

Standby operation was requested by the City of Battle Creek by The Dow Chemical Company on April 27 and granted on May 8. A meeting in Cincinnati on May 29 (W. W. Towne, E. H. Bryan, and A. E. Becher) established the nature of continued work at Battle Creek. The Dow Chemical Company agreed to reimburse the city for expenses incurred in the remaining portion of the study which began June 4 and was concluded on July 3, 1956. The principal objective between June 4 and July 3 was to operate the unit at a relatively low hydraulic rate of application in order to furnish a closer tie to conventional rates for both standard and high rate trickling filtration. Further operation was thought desirable, but impracticable.

DESCRIPTION OF PILOT PLANT

The Dowpac HCS used in this pilot plant was fabricated from Styron* 475 a high impact polystyrene plastic. Individual corrugated sheets, 37-1/2 inches long and 21 inches wide were assembled to form a pack 37-1/2 inches square and 21 inches deep with an average sheet spacing of approximately one inch. The packing had a unit weight of 4 pounds per cubic foot, a surface area to volume ratio of 25 square feet per cubic foot, and void space of 95%.

The tower provided a total packed depth of 42 feet with a cross sectional area of 9.76 square feet. The tower is shown in Figure 1 during construction. Plastic sheets were used as a siding for the tower to prevent cross-ventilation and loss of liquid. The packing was supported on two beams (2" x 4" wooden members). A timber scaffold was constructed around the Dowpac HCS "core" to provide lateral support for the tower and to provide a support for intermediate platforms and a ladder. A metal tray suspended beneath the beams served as an underdrain. The completed structure is shown in Figure 2. Battle Creek Sewage Treatment Plant primary effluent was pumped to the top of the tower by a self-priming centrifugal pump through an orifice-type flow regulator (Figure 3) and distributed by means of a reaction-driven rotary distributor. (Figure 4)

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*Trade mark of The Dow Chemical Company

The pilot plant effluent flowed by gravity to a rectangular sedimentation tank with a volume of 366 cubic feet and surface area of 75 square feet. (Figure 5) Sludge was scraped with a long handle, manually operated, scraper and was drawn off daily through a valve provided for this purpose (Figure 6). A pump was provided to permit return of unsettled tower effluent to the top of the tower for recirculation studies.

To permit visual inspection and sampling at intermediate depths, the packing was interrupted at 10.5-foot increments. One of these sampling ports is shown in Figures 7 and 8. Automatic composite samples were collected of the influent, tower effluent and secondary tank effluent by means of solenoid operated valves controlled with electrically driven interval timers. A schematic drawing of the sampling stations is shown in Figure 9. Points A, B, and D represent automatic sampler locations.

PILOT PLANT OPERATION

The tower was placed in operation on January 13 at a hydraulic application rate of 33.1 gpm. This operation was continued until February 3 before sampling was started. At that time, slime was evident at all levels of the tower although, as with all application rates studied, the upper portions appeared to have significantly greater amounts.

Subsequently, in order, rates of 15.9 gpm, 32 gpm (1:1 recirculation with a nominal application of 16 gpm of primary effluent), 8 gpm, and 3.1 gpm were studied. Hydraulic data pertinent to these rates are summarized in Table 1 and in Appendix Table A-1. Although a rotary distributor was used (Figure 4), calculated hydraulic and organic loadings in this report are based upon the assumption that all packing in the tower contributed to its performance.

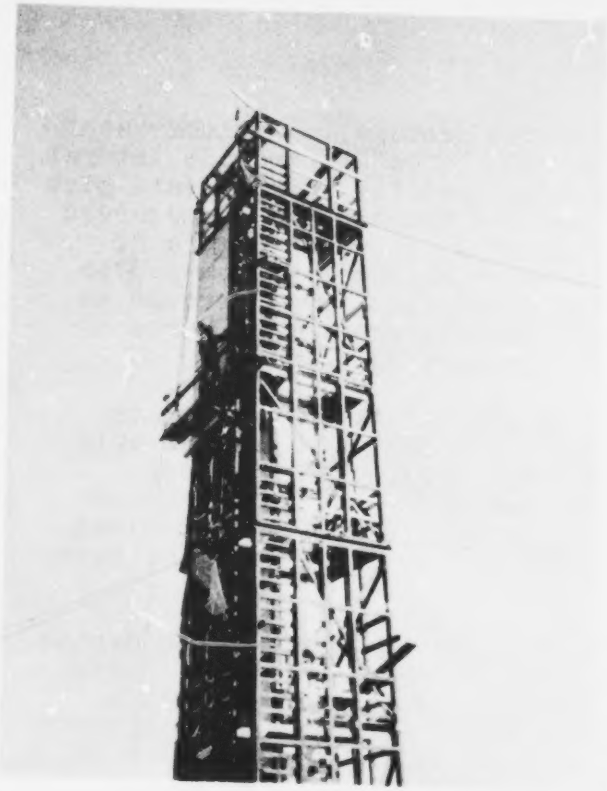
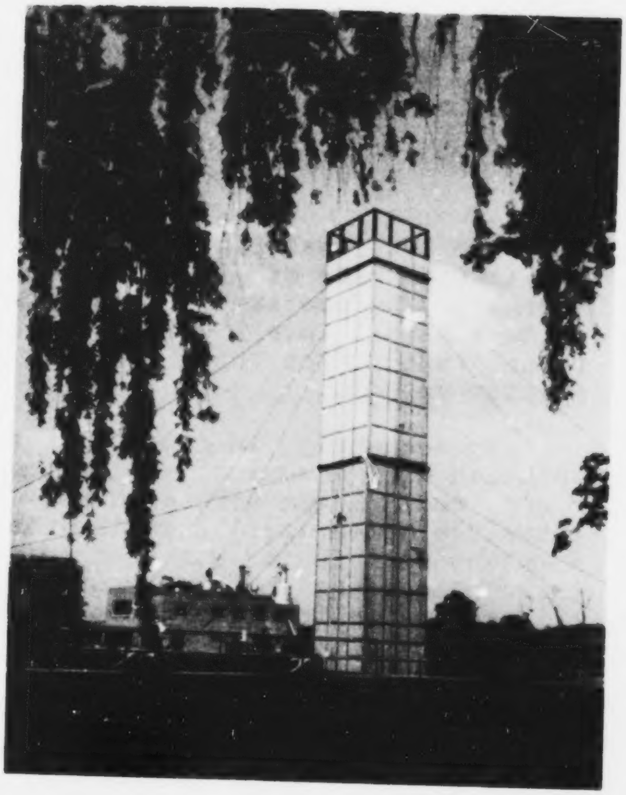


Fig. 1 - Dowpac HCS Pilot Plant Tower Under Construction at Battle Creek, Michigan

Fig. 2 - Dowpac HCS Pilot at Battle Creek, Michigan



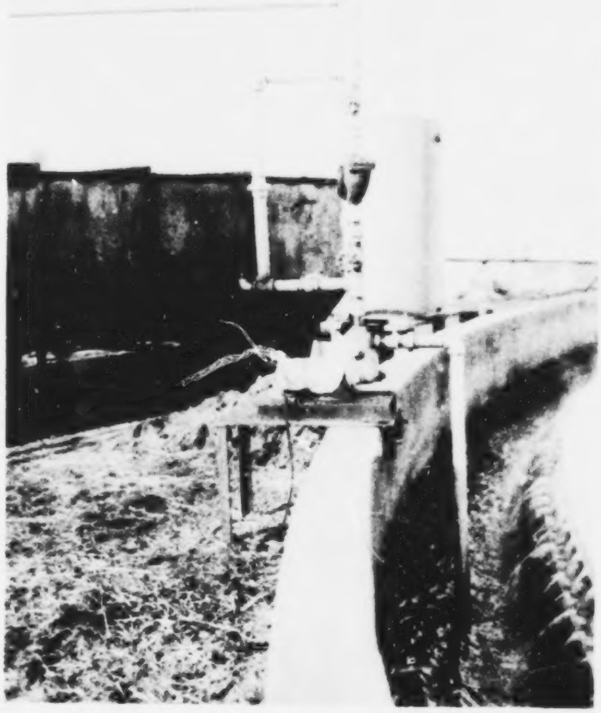


Fig. 3 - Pump for Application of Effluent From City of Battle Creek Sewage Treatment Plant Primary Sedimentation Tank to the Dowpac HCS Tower

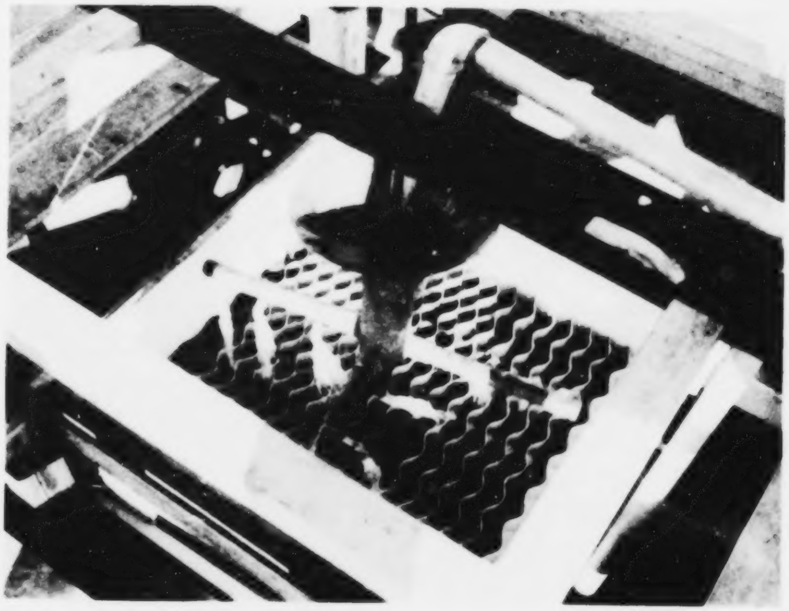


Fig. 4 - Rotary Distributor Shown Applying Settled Sewage to the Dowpac HCS Tower at Battle Creek (33.1 Gallons per Minute)

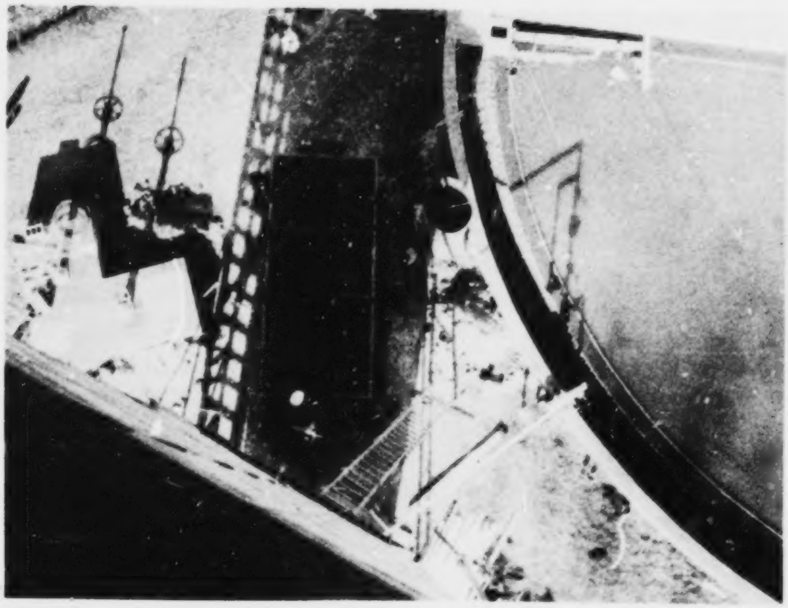


Fig. 5 - Pilot Plant Final Settling Tank Viewed From Top of Tower

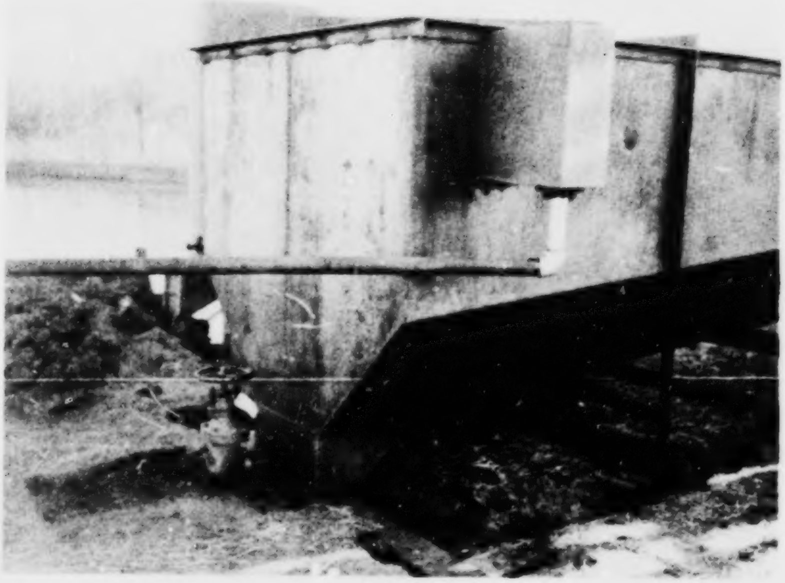


Fig. 6 - Pilot Plant Final Settling Tank Showing Sludge Withdrawal Valve and Effluent Pipe.

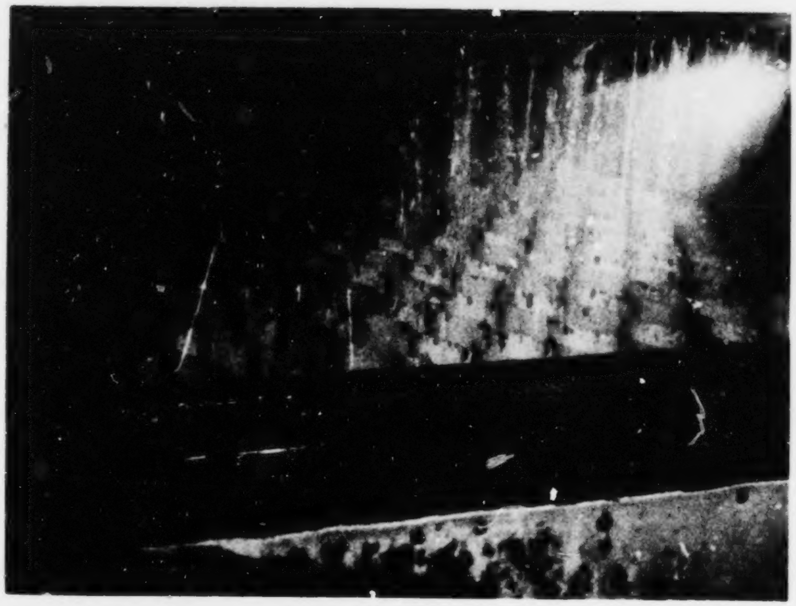


Fig. 7 - Intermediate Section of Dowpac HCS Tower Showing Liquid Distribution Prior to Extensive Slime Build-up at 33.1 Gallons per Minute

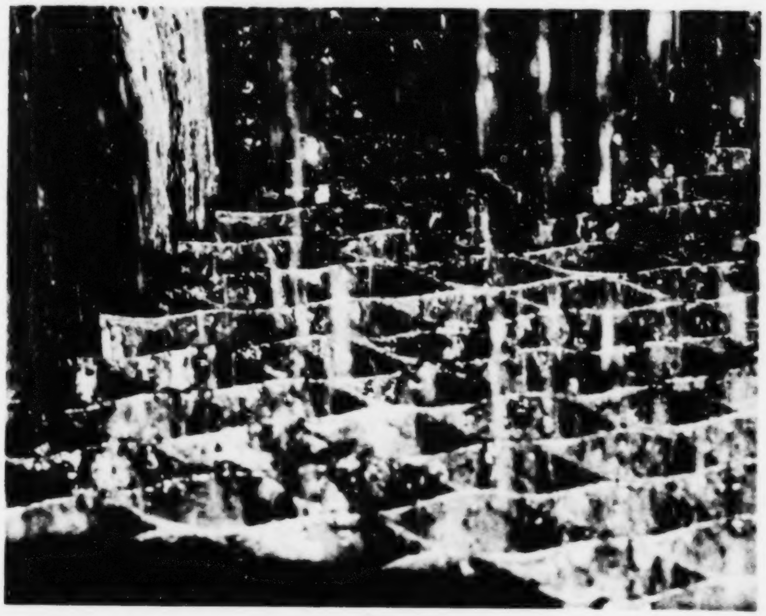


Fig. 8 - Slime Accumulation at an Intermediate Section in the Dowpac HCS Tower at Battle Creek Following Several Months of Operation. Hydraulic Rate of Application - 3.1 Gallons per Minute

CODE TO SAMPLING STATIONS
BATTLE CREEK DOWPAC HCS PILOT PLANT

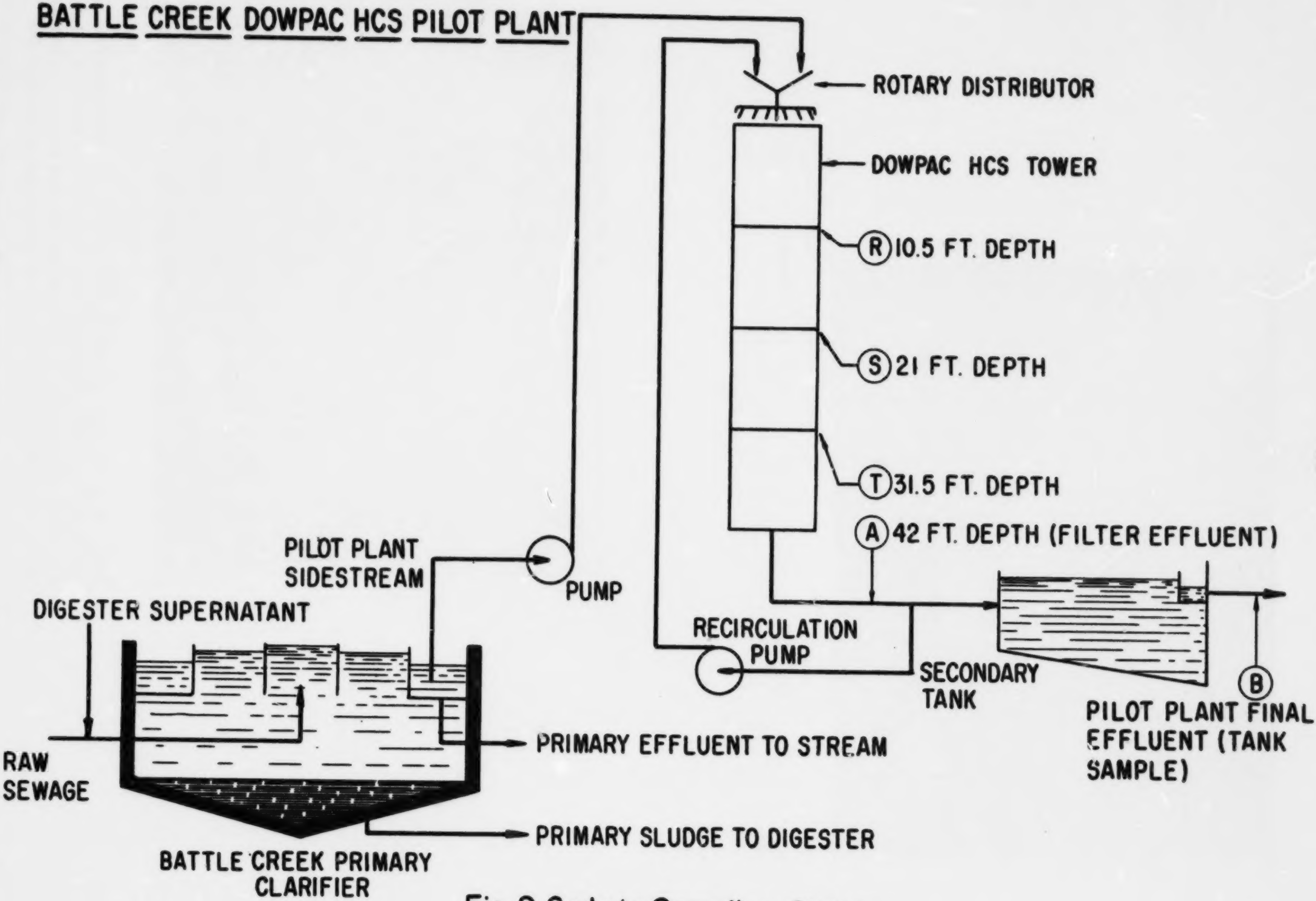

ROTARY DISTRIBUTOR
DOWPAC HCS TOWER
Ⓡ 10.5 FT. DEPTH
Ⓢ 21 FT. DEPTH
Ⓣ 31.5 FT. DEPTH
Ⓐ 42 FT. DEPTH (FILTER EFFLUENT)
PILOT PLANT SIDESTREAM
PUMP
DIGESTER SUPERNATANT
RECIRCULATION PUMP
SECONDARY TANK
Ⓑ
PILOT PLANT FINAL EFFLUENT (TANK SAMPLE)
RAW SEWAGE
PRIMARY EFFLUENT TO STREAM
PRIMARY SLUDGE TO DIGESTER
BATTLE CREEK PRIMARY CLARIFIER

Fig. 9. Code to Sampling Stations

Table I
Schedule of Operating Hydraulic Rates

Dates 1956	Tower Hydraulic Application Rates GPM	Tower Hydraulic Application Rates MGAD	Sedimentation Tank Surface Loading (GPD/sq.ft.	Sedimentation Tank Theoretical Detention Time (Hours)
Jan. 13-Feb. 17	33.1	213	636	1.38
Feb. 17-March 4	15.9	102	305	2.87
March 4-April 8	32(16:16)	206	310	2.9
April 8-April 29	8	51	154	5.7
June 5-June 27	3.1	20	(60)*	(15)*

*Note: Although surface loading and detention time values are listed for the 3.1 gpm rate, the tank was not used at this rate.

Abbreviations: MGAD - Million gallons per acre per day
GPM - Gallons per minute
GPD/sq.ft.- Gallons per day per square foot

Following each change in application rate a period of time was allowed to elapse before sampling was commenced to permit the tower to reach equilibrium. In the period between April 29 and June 5 the tower was operated on a stand-by basis at approximately 8 gpm. During all operating periods application rates were checked at least once daily. Except for the period of recirculation when some difficulty was experienced with the primary effluent pump, no difficulty was experienced in maintaining constant application rates.

The pilot sedimentation tank (Figures 5 and 6) was of fixed volume. Hydraulic loadings consequently varied when the tower application rates varied. These loadings are shown in Table 1. Generally surface loadings and detention times were considered sufficiently conservative by comparison with design standards to provide maximum performance obtainable within the limitations of this particular tank. The detention time and surface loading at the 8 gpm rate were 5.7 hours and 154 gallons per square foot per day. There was no apparent statistically significant loss of effluent quality attributable to the relatively long detention period and low settling rate (comparison with conventional design standards). The tank was not used at the 3.1 gpm rate because the theoretical detention time was so great that results would have been definitely questionable, particularly in view of the warmer temperatures. Nuisance conditions would undoubtedly have developed, if the tank had been used.

Initially sludge was removed from the sedimentation tank by opening the sludge withdrawal valve. When this procedure was observed to be completely inadequate, (On February 11, the tank was almost full of digesting sludge) a long handled scraper was obtained and used to move accumulated sludge to the withdrawal valve. Once daily, discharge was maintained through this valve until the liquid appeared clear. This usually took from 2 to 5 minutes. Sludge was drawn at 12:15 P.M. each day at the conclusion of intensive tower sampling. Throughout the study considerable difficulty was experienced in removing sludge from the tank.

Sampling and Analytical Procedures

To determine the optimum frequency and duration of sampling, hourly samples of primary effluent (Tower influent) were collected from 3:00 P.M. January 31 to 4:00 P.M. February 10, for C.O.D. analysis. On the basis of these results it was determined to use the 8-hour compositing periods, 4:00 P.M. to 12:00 M, 12:00 M to 8:00 A.M. and 8:00 A.M. to 4:00 P.M. These periods also coincided well with normal Battle Creek Sewage Treatment Plant operating schedules. Samples of the tower influent, tower effluent and final tank effluent were collected and composited automatically at ten minute intervals (Points D, A, and B, Figure 9). These 8-hour composites were also used to make up 24-hour composites. The period 4:00 P.M. to 4:00 P.M. was used for 24-hour composite samples from February 3 through March 14 and the period 8:00 A.M. to 8:00 A.M. used for subsequent samples. Samples at all points including intermediate stations were also collected manually and composited at 30 minute intervals from 8:00 A.M. to 12:00 Noon inclusive. A detailed summary of sampling schedules for the entire period of study is shown in Appendix Table A-1.

Automatic samples were collected by means of solenoid-operated valves installed in the lines to be sampled and activated by electric interval timers. Samples were discharged to containers suspended under the valves. The accumulated contents of each container was stirred thoroughly prior to removal of a sample for analysis. Containers were emptied at the conclusion of each compositing period. Samples at intermediate depths (Points R, S, and T, Figure 9) were collected by sweeping a piece of aluminum tubing, which had been split to form a trough, through the space between packing depth increments. The contents of the tube were placed in a bottle following each "sweep". Samples were also collected manually in a bottle at points D, A and B, Figure 9. Following collection all samples were stored in a refrigerator at 4°C. until analyses were made.

To study performance of the tower followed by uniform sedimentation at all hydraulic rates, tower effluent samples (point A) were settled uniformly in the laboratory. Automatically collected 8-hour and 24-hour composites were settled by placing 600 ml. in a 500 ml.

graduated cylinder, allowing 60 minutes of quiescent settling, and decanting the top 300 ml. for analysis. Manually collected composites were settled by placing 1,000 ml. in a 1,000 ml. graduated cylinder allowing 30 minutes of quiescent settling, syphoning to the 1,000 ml. mark to clear the syphon and then syphoning 300 ml. for analysis.

Analytical determinations included 5-day Biochemical Oxygen Demand at 20°C., Chemical Oxygen Demand by the dichromate-reflux method using silver sulfate catalyst, Suspended Solids, and Volatile Suspended Solids. Temperature was also recorded at regular intervals throughout the period of sample collection. The Chemical Oxygen Demand reflux time was set at one hour after it had been established that there was no significant difference between duplicate samples refluxed for both one hour and two hours. In other respects procedures followed were as described in *Standard Methods for the Examination of Water, Sewage and Industrial Wastes*, 10th Edition. Chemical Oxygen Demand apparatus in the laboratory annex is shown in Figure 10 and the water bath incubator used for Biochemical Oxygen Demand determinations (with cover removed) is shown in Figure 11.

B.O.D. and C.O.D. determinations were run in duplicate from February 3 to March 2. Duplicate determinations were discontinued at that time because of the close agreement between results of duplicates.

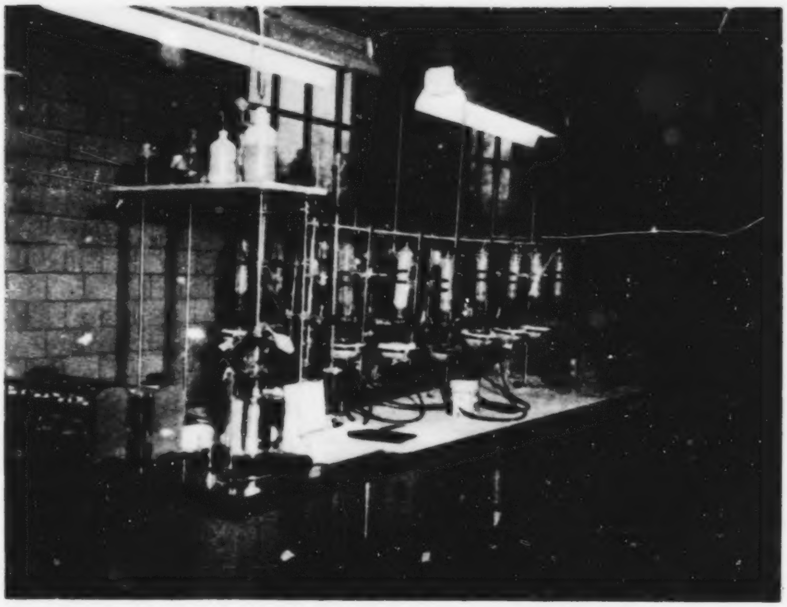


Fig. 10 - Laboratory Equipment Assembled for Determination of Chemical Oxygen Demand at Battle Creek, Michigan during Pilot Plant Study.

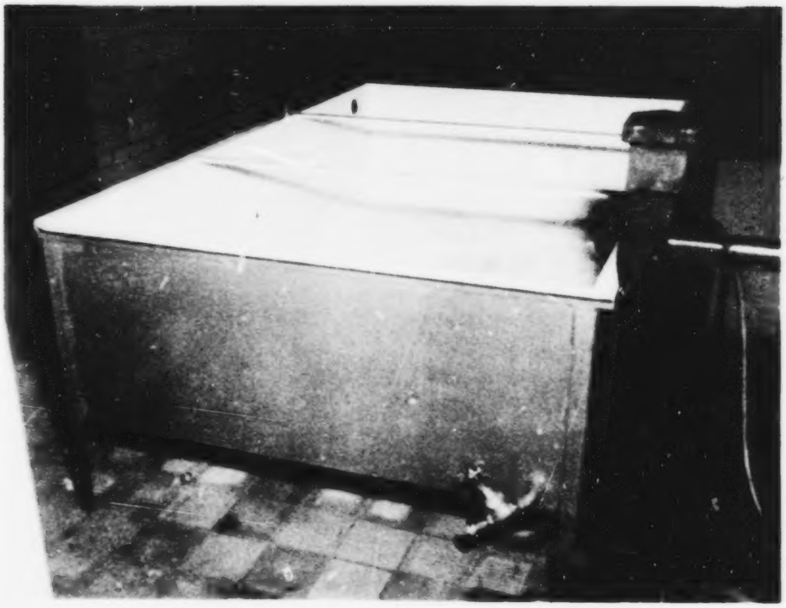


Fig. 11 - Supplementary B.O.D. Incubator Installed at the Battle Creek Sewage Treatment Plant Laboratory (Cover Removed)

SOME CHARACTERISTICS OF BATTLE CREEK SEWAGE

To assist in selection of sampling periods, a study was conducted to determine the variation in the strength of effluent from the Battle Creek Sewage Treatment Plant at hourly intervals for seven consecutive days. Data obtained included the Chemical Oxygen Demand and discharge rate. These data and the calculated total organic load contained in the effluent are plotted in Figure 12. All hourly data from which Figure 12 was plotted are contained in Table A-2 (Appendix). For convenience in plotting, data for alternate hours were used to construct Figure 12. Mean daily values have been determined from data in Table A-2 for this period and are presented in Table 2.

Table 2

Summary of Battle Creek Pilot Plant Influent Data Obtained During Preliminary Survey to Aid in Establishing Sampling Schedules

Date (1956)	Day of the Week	Mean Flow (MGD)	Chemical Oxygen Demand Concentration (ppm)	Chemical Oxygen Demand Total Load (1000 lb./day)
Jan. 31	Tuesday	7.58	400	25.70
Feb. 1	Wednesday	--	--	--
Feb. 2	--	--	--	--
Feb. 3	Friday	6.52	548	29.46
Feb. 4	Saturday	5.22	384	17.30
Feb. 5	Sunday	6.44	344	19.53
Feb. 6	Monday	7.56	585	36.67
Feb. 7	Tuesday	7.62	532	34.06
Feb. 8	Wednesday	7.97	509	34.08
Feb. 9	Thursday	8.02	499	33.65
Feb. 10	Friday			
Mean Weekly Feb. 3-10		7.05	486	29.25

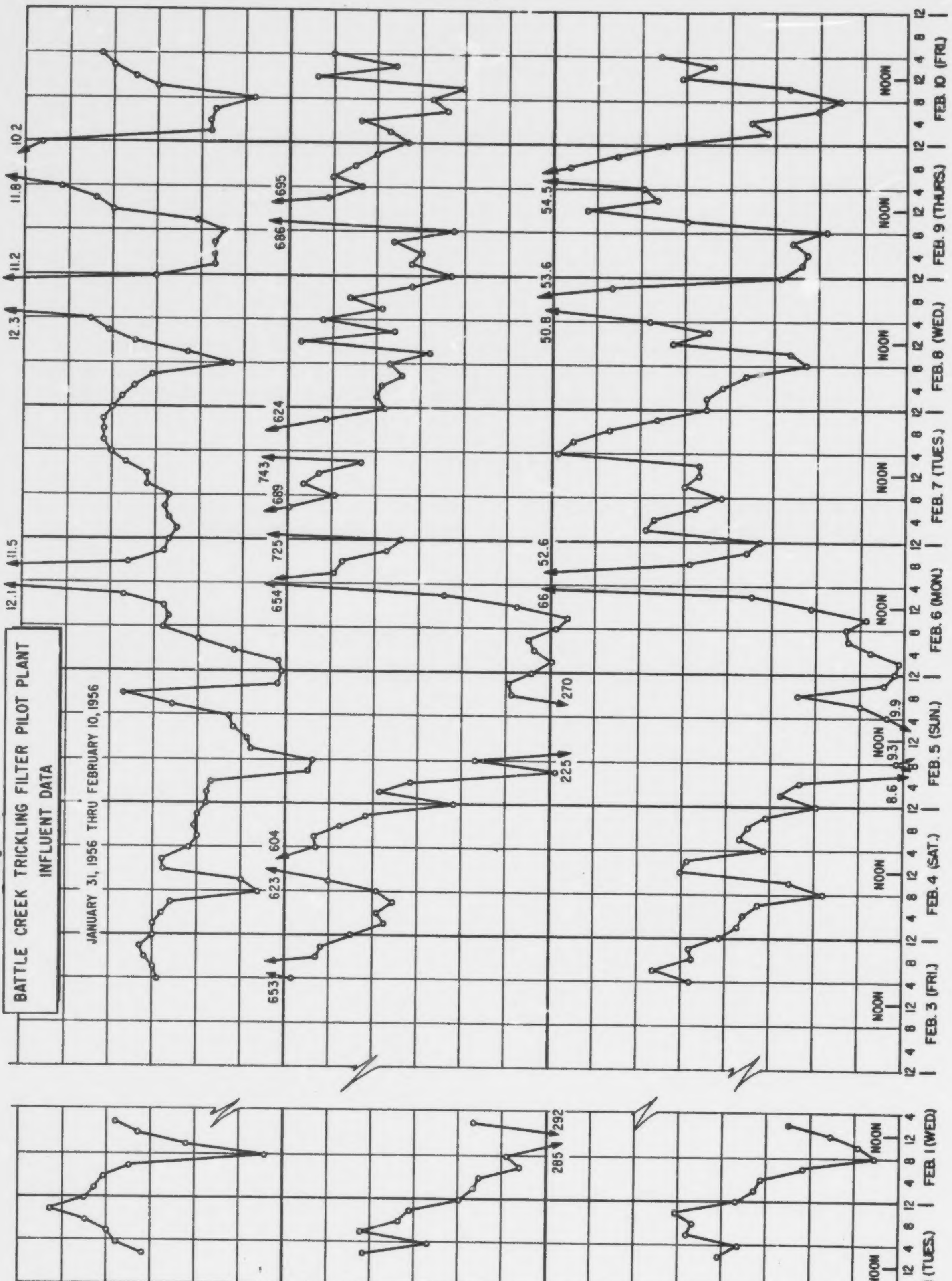


Fig. 12

BATTLE CREEK TRICKLING FILTER PILOT PLANT
INFLUENT DATA

JANUARY 31, 1956 THRU FEBRUARY 10, 1956

During the week of February 3-10, 1956, the mean daily flow was 7.05 million gallons per day, the Chemical Oxygen Demand of the treatment plant effluent was 486 parts per million, resulting in a total daily Chemical Oxygen Demand (COD) load to the stream of 29,250 pounds. If the ratio of 5-day BOD to COD as obtained from averages in Table 3 is assumed to be applicable, the equivalent discharge of 5-day BOD to the receiving stream was approximately 16,550 pounds per day (282 ppm).

In order to better characterize the properties of the pilot plant influent with respect to both the 5-day Biochemical Oxygen Demand and Chemical Oxygen Demand, data taken by pilot plant personnel during the study are presented in Table 3. Where comparative data were available, 24-hour composites and means of three 8-hour composites were in agreement.

Table 3

Summary of Battle Creek Pilot Plant Influent Data Obtained During Operation of the Pilot Plant

Time Interval (1956)	Hydraulic Rate Applied to Pilot Plant (GPM)	5-Day Biochemical Oxygen Demand				Chemical Oxygen Demand			
		Observations	Concentrations (ppm)			Observations	Concentrations (ppm)		
			Maximum	Minimum	Mean		Maximum	Minimum	Mean
Feb. 3-17	33.1	13	314	146	249	14	583	303	453
Feb. 17-Mar. 14	15.9	24	317	119	222	24	496	242	389
Mar. 20-Apr. 7	16 direct + 16 recycle	15*	370*	194*	241*	15	634	330	420
Apr. 10-28	8.0	15*	291*	171*	227*	15	498	304	397
June 11-27	3.1	16	261	143	218	16*	472*	280*	393*
Total Number of Observations and Mean Values		83	311	151	230	84	531	286	407

Notes: *Based upon 24-hour composite samples. All others based upon mean of three 8-hour composites

Ratio: $\text{Mean}\ \frac{\text{5-Day B.O.D.}}{\text{C.O.D.}} = \frac{230}{407} = 0.565$

To provide further basis for a characterization of Battle Creek sewage, a tabulation of selected data from the treatment plant monthly operational reports is presented in Appendix Table A-42. These data have been further summarized in Table 4.

Table 4

Selected Mean Data From Monthly Summaries of Operation, Sewage Treatment Plant, Battle Creek, Michigan

		Mean Values Jan. - Apr., 1956
Population Served		51,950
Daily Flow - Million Gallons per Day (MGD)		8.17
Per capita Volume - Gallons Per Day		157
Influent:	5-Day BOD - Lb./Day	19,280
	5-Day BOD - Lb./Capita/Day	0.371
	Suspended Solids - Lb./Day	14,475
	Volatile Suspended Solids - Lb./Day	11,800
Effluent:	5-Day BOD - Lb./Day	15,320
	5-Day BOD - Lb./Capita/Day	0.296
	Suspended Solids - Lb./Day	6,810
	Volatile Suspended Solids - Lb./Day	5,500
Performance -	Removal of 5-Day BOD	20.5%
	Removal of Suspended Solids	53.0%

Concentrations of 5-day BOD, suspended and volatile suspended solids calculated from values in Table 4 are presented in Table 5 and compared with mean values obtained during the pilot plant study.

Table 5

Concentrations Calculated From Values in Table 4 Compared With Data Obtained During Pilot Plant Study

Source	Analysis	Concentrations in ppm	
		Raw Sewage	Primary Effluent*
Table 4	5-Day BOD	283	225
Table 4	Suspended Solids	213	100
Table 4	Volatile Suspended Solids	174	81
Table 3	5-Day BOD	-	230
Table A-37	Suspended Solids	-	79
Table A-37	Volatile Suspended Solids	-	68

*Pilot Plant Influent

During the period from January through April inclusive, the average population served by the Battle Creek sewage treatment plant was approximately 51,950. Since the average daily flow was 8.17 million gallons, the average daily per capita volume contribution was 157 gallons. This is in excess of the value 100 gallons per capita per day usually considered as average.

The above-average per capita volume contribution was not accompanied by a reduction in concentration of Biochemical Oxygen Demand as would be expected if the additional water volume was uncontaminated. The total mean 5-day BOD was 19,280 pounds per day in the raw sewage or approximately 0.37 pounds per capita per day. This is about 2-times the value usually accepted as an average per capita contribution. Since the above-average daily per capita volume contribution was not proportionately as large as the excess in quantity of organic load, the resultant concentration of 5-day BOD in the raw sewage received at the treatment plant was somewhat larger than that for a normal medium strength domestic sewage. The mean concentration of 5-day BOD of the raw waste was 283 parts per million. The mean concentration of 5-day BOD in the effluent (which was the pilot plant influent) was approximately 225 ppm. During the period January through April, the mean efficiency of the plant was 20.5%. The large improvement in treatment plant efficiency in May and June (see Table A-42) was probably attributable to seasonal changes in the quality of raw sewage.

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In comparison with a typical sanitary sewage, the concentration of suspended solids was characteristic of a medium-weak sewage while the concentration of 5-day BOD was characteristic of a strong sewage. The relatively low concentration of suspended solids in contrast to a high concentration of biochemically oxidizable matter indicated that a greater than "typical" proportion of the oxygen-demanding substances were in solution and colloidal suspension.

In order to more accurately simulate conditions under which a full scale secondary treatment plant would be required to operate, supernatant liquor from the digesters was returned to the primary tanks during this pilot study. All known contributors of biologically-toxic substances were requested to refrain from discharging their wastes in slugs. Since analyses were not made for these substances on a routine basis, it is not known how effective this request was.

Mean air and sewage temperatures are contained in Table 6. Air temperatures varied from a low reading of 2°F. on January 23 to a high of 95°F. on June 12. During the period from January 13 through April 29, the temperature of the tower influent (sewage) varied from a low reading of 48°F. to a high of 60°F. During this period, the minimum recorded temperature of the tower effluent was 44°F. and the maximum was 59°F. The range in variation of daily mean values is not as great. This is evident from data in Table 6.

Table 6

Temperatures of Air and Waste

Month 1956	Temperatures - Degrees Fahrenheit				
	Air - Mean Daily			Tower Influent	Tower Effluent
	Average	Maximum	Minimum		
January	22.6	31.0	14.0	--	--
February	26.2	37.5	17.0	56.4	53.4
March	31.8	41.5	17.5	53.3	48.6
April	45.6	67.5	34.5	55.4	53.1
May	--	--	--	--	--
June	75.2	83.0	64.0	66.5	--

PRESENTATION AND DISCUSSION OF RESULTS

A summary of performance based upon removal of 5-day Biochemical Oxygen Demand is contained in Table 7. Samples were collected automatically and composited as described in "Sampling and Analytical Procedures." Daily variations in loading and performance are tabulated in the Appendix and are plotted in Figures 13 and 14.

Table 7

Dowpac HCS Tower Performance Based Upon 5-Day BOD

(Automatically Collected Samples)

Tower Depth - 42 Feet

Hydrau. Rate (GPM)	Composit. Interval (Hours)	Organic Loading Lb. BOD/1000 ft^3/day			BOD Efficiency - Percent Removal					
					With Tank			With Lab Settling		
		Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.
33.1	8	305	241	142	46.7	34.0	21.5	59.3	48.1	40.0
	24	-	-	-	-	-	-	59.3	48.1	40.0
15.9	8	148	103	71.0	74.6	56.0	30.4	82.5	68.1	49.5
	24	123	83.2	47.4	-	-	-	81.4	71.9	63.1
8.0	8	-	-	-	-	-	-	-	-	-
	24	68.0	53.0	40.0	87.6	76.8	47.1	84.5	80.3	69.7
3.1	8	23.8	19.9	13.0	-	-	-	91.4	85.9	69.9
	24	23.9	19.9	13.6	-	-	-	91.6	86.7	72.5
16 dir. plus 16 recirc.	8	-	-	-	-	-	-	-	-	-
	24	134	101	75.0	67.8	62.2	43.7	75.5	66.7	47.0

A summary of performance based upon removal of Chemical Oxygen Demand is contained in Table 8. Daily variations are tabulated in the Appendix and are also plotted in Figures 13 and 14. Individual data for each hydraulic rate are presented in the section containing miscellaneous figures (Figures C-20, C-21, C-22, C-23 and C-24).

Table 8

Dowpac HCS Tower Performance Based Upon Chemical Oxygen Demand

(Automatically Collected Samples)

Tower Depth - 42 Feet

Hydrau. Rate (GPM)	Composit. Interval (Hours)	Organic Loading Lb. COD/1000 ft3/day			COD Efficiency - Percent Removal					
					With Tank			With Lab Settling		
		Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.
33.1	8	566	440	294	37.7	29.2	16.0	51.2	44.9	37.9
	24	-	-	-	-	-	-	51.2	44.9	37.9
15.9	8	240	182	113	64.2	47.3	23.2	78.3	56.5	41.2
	24	191	156	112	66.6	52.4	43.8	73.7	60.3	44.5
8.0	8	117	93.0	71.0	75.9	65.3	51.6	81.9	69.5	60.6
	24	118	92.9	75.8	84.2	63.5	34.1	92.8	69.2	56.7
3.1	8	-	-	-	-	-	-	-	-	-
	24	43.0	35.8	29.2	-	-	-	80.3	72.2	48.3
16 dir. plus 16 recirc.	8	236	176	131	58.6	50.7	41.2	62.6	53.7	39.8
	24	-	-	-	61.6	49.3	35.7	60.8	51.1	37.1

From data presented in Tables 7 and 8, and Figures 13 and 14, it is apparent that considerable variation in performance occurred at any given application rate. However, it is also apparent that performance generally became better as the application rate was decreased. These data can also be used to compare the laboratory settling method with the pilot plant sedimentation tank. With respect to both removal of biochemical and chemical oxygen demand, the laboratory settling procedure in all instances gave better results.

Some data were obtained which may be used to compare the laboratory settling procedure directly with the pilot-scale sedimentation tank, exclusive of the tower. Those summarized in Table 9 are based upon manually collected and composited samples taken over four-hour periods (see Sampling and Analytical Procedures).

Table 9

Summary of Tank and Laboratory Settling Performance Exclusive of Tower

(Based on 4-hour Composite of Manually Collected Samples at 42 foot Depth)

Dowpac HCS Tower Hydrau. Loading Rate		Hydraulic Properties of Tank		Mean Performance - Percent Removal			
				Suspended Solids		5-Day BOD	
GPM	MGAD	Settling Rate GPD/Ft.^{2}	Theoretical Detention Time-Hrs.	Settling Tank	Lab Cylinder	Settling Tank	Lab Cylinder
33.1	213	636	1.38	-	-	15.0	-
15.9	102	305	2.87	48.7	36.6	-	-
16 + 16*	206	614	1.43	44.8	30.2	-	-
8.0	51	154	5.70	51.7	34.3	-	-
3.1	20	Tank was not used		-	62.1	-	16.1
Mean	-	-	-	48.4	33.7**	-	-

* 16 GPM Direct plus 16 GPM Recirculation

**Excluding Efficiency at 3.1 GPM

BATTLE CREEK DOWPAC PILOT PLANT
PERFORMANCE DATA - BASED ON 24 HR. COMPOSITIES

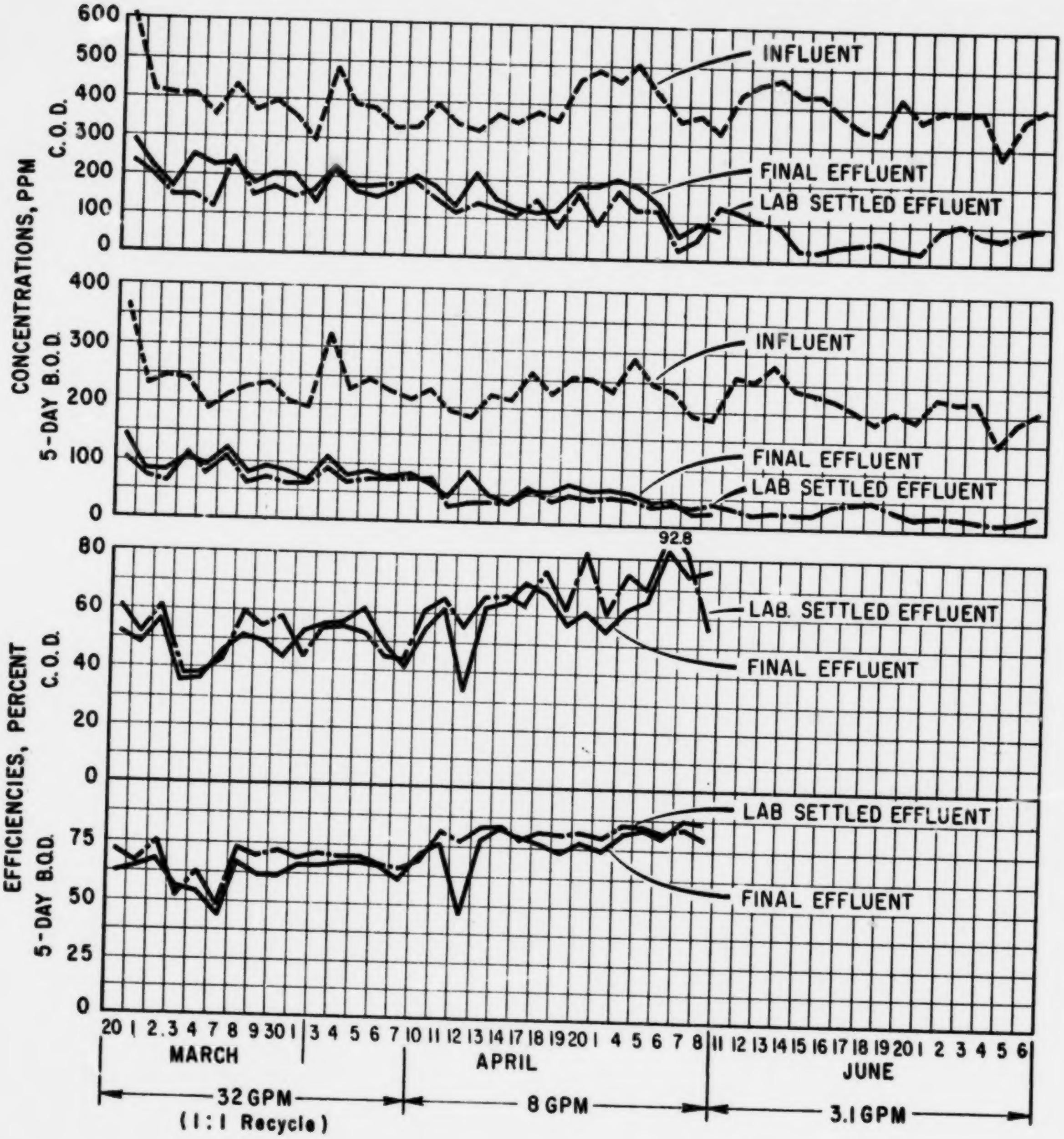

Fig. 13

BATTLE CREEK DOWPAC HCS PILOT PLANT
MEAN DAILY DATA - BASED ON 8 HR. COMPOSITES

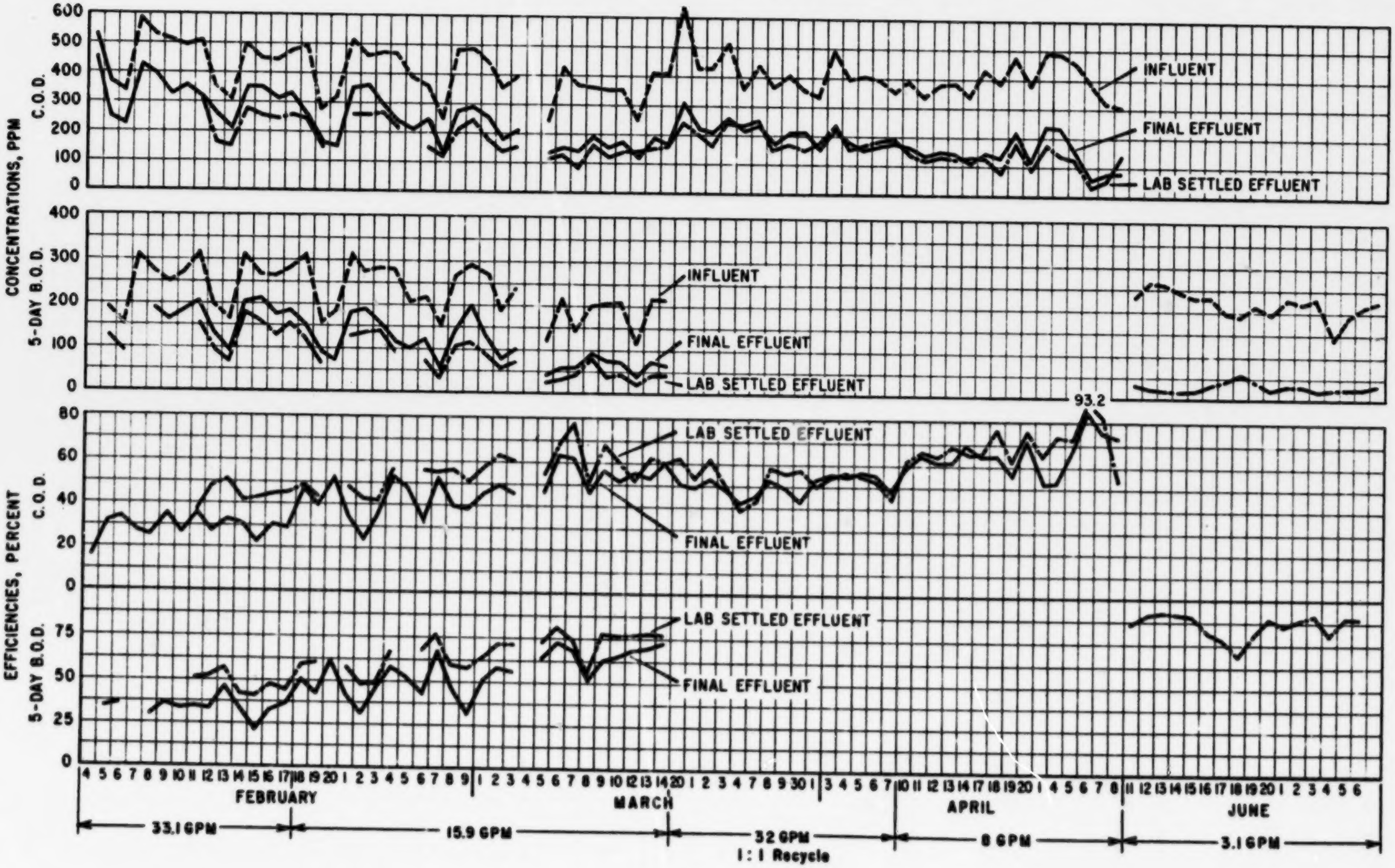

Fig. 14

From the data summarized in Table 9, that is, using percent removal of suspended solids as a criterion, performance of the tank was better than that achieved by the laboratory settling procedure. A significantly higher percent removal of suspended solids from the tower effluent by laboratory settling was observed during the period of operation at 3.1 gallons per minute than was observed during operation at all other hydraulic rates. Factors that may account for this include:

1. A possibility that a change occurred in the effect of the Dowpac HCS tower on the settling characteristics of its effluent as a result of only the reduced hydraulic rate of application.

2. A change in quality of raw sewage attributable to seasonal variations in industrial activity.

There is an apparent conflict in conclusions that may be reached regarding performance of the tank versus laboratory settling procedures. Using removal of 5-day biochemical oxygen demand or chemical oxygen demand as criteria, 60 minutes of quiescent laboratory settling resulted in more removal than tank settling. Using removal of suspended solids as a criteria, the tank removed more suspended solids than were removed in 30 minutes of laboratory settling. All data involved in this apparent conflict are not directly comparable with respect to sampling intervals or settling technique. Relationships between BOD, and COD and suspended solids were not defined by data taken with respect to various positions in the pilot plant stream. No attempt was made to establish a relationship between these measures of organic load and sampling periods. Mechanisms other than sedimentation may have been involved in removal of organic load during "sedimentation." There was a possibility that adsorbed, unstabilized organics were released during sedimentation or that intermittent removals of sludge from the tank may have allowed its partial decomposition during storage. It was, therefore, not considered possible to reconcile what may appear to be conflicting statements regarding the relative performance of settling techniques used during this study. Design criteria for final sedimentation in terms of practicability although of great importance in reducing these results to practical design, were not considered within the scope of this study.

Statistical Analysis of 5-day BOD-Removal Data

With the exception of automatically collected, laboratory settled samples, with respect to removal of 5-day Biochemical Oxygen Demand, it was impossible to statistically distinguish between automatic and manual sampling methods or between tank settling and laboratory settling procedures. Therefore, in the following analysis, all BOD-removal data were used except those based upon samples that were automatically collected and laboratory settled.

Because of variations in strength of primary effluent and impracticability of compensating for them, organic loadings applied to the pilot plant tower varied in accordance with the concentration of organic matter in the waste stream. The variation was too small however to statistically relate performance independently to organic loading at any hydraulic loading. Data plotted to illustrate performance as a function of organic loading (C-6 to C-10, inclusive) indicate that within the range of organic loading at any single hydraulic loading, performance was independent of organic loading. Consequently, hydraulic loading (Q) and sampling depth (D) were the only independent variables considered in this analysis. Predictions of Dowpac HCS tower efficiency as a function of "Q" and "D" can only be strictly valid for sewage with the same range of organic composition as that used in this study. Since the temperature range of the applied sewage was small, no attempt was made to apply a temperature correction to the data. Predictions made on the basis of these results are consequently only valid for the range of temperatures observed during the study.

The objective of the statistical analysis was to determine a single mathematical equation which would estimate percentage BOD-removal as a function of filter depth and hydraulic loading, and to determine the reliability of this equation as a predictor, that is, to determine the "standard error of estimate". Several mathematical models were tried, with varying degrees of success.

Model I. Under the assumption that $\frac{dR}{dt} = kR$, where R = fraction of BOD remaining and t = contact time, an equation: $R = 10^{Kt}$, is obtained. Theoretically, by principles of fluid mechanics, time of flow (t) can be expressed as a function of filter depth (D) and hydraulic loading (Q). Howland* indicates the relationship:

$$t = C\frac{D}{Q^p} \quad \text{where} \quad p = \frac{2}{3} \text{ for laminar flow conditions.}$$

The resulting model equation, $R = 10^{-KD/Q^p}$ was linearized and fitted to the data by the method of least squares as follows:

$$y = \log_{10}(-\log_{10}R)$$

$$= \log_{10}K + \log_{10}D - px, \text{ where } x = \log_{10}Q$$

However, the data did not conform well to this model. The geometric spacing between the curves for different D-values was apparently adequate but experimentally determined values of "R" did not decrease as rapidly with increasing values of "Q" as the fitted equation predicted. That is, for given "D", "y" versus "x" was curvilinear rather than linear (Figure 15).

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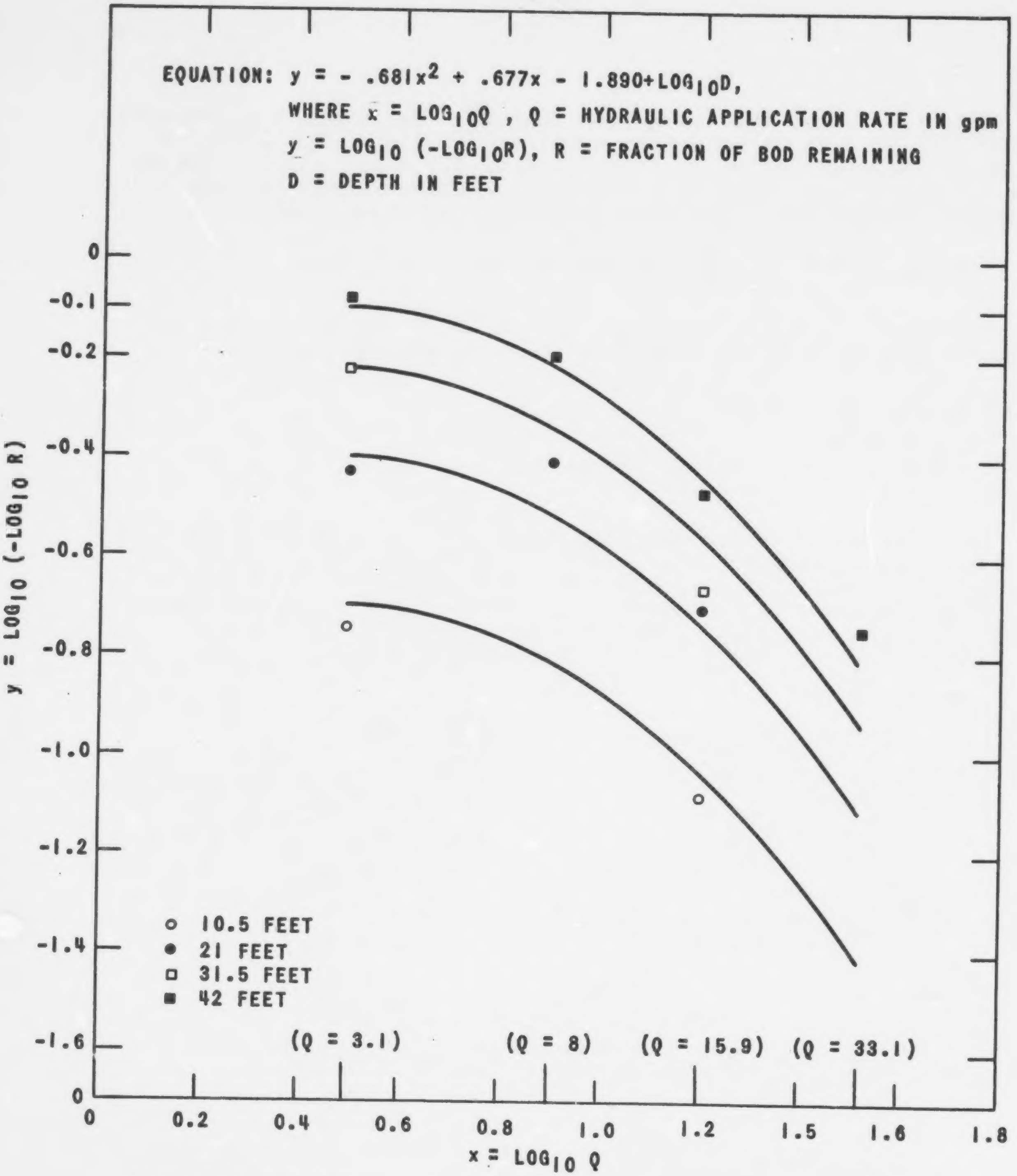
*Howland, W. E., Flow over porous media as in a trickling filter. Presented at The 12th Purdue Industrial Waste Conference



LEAST-SQUARES FIT OF A QUADRATIC TRANSFORM OF MODEL I TO OBSERVED FRACTIONS OF BOD REMAINING AT GIVEN HYDRAULIC RATES (POINTS PLOTTED ARE MEANS OF REPLICATE RUNS)

Figure 15

Because of the preceding considerations, a quadratic term in "x" was added, and a new equation fitted. Solution by use of the method of least squares gave the following equation:

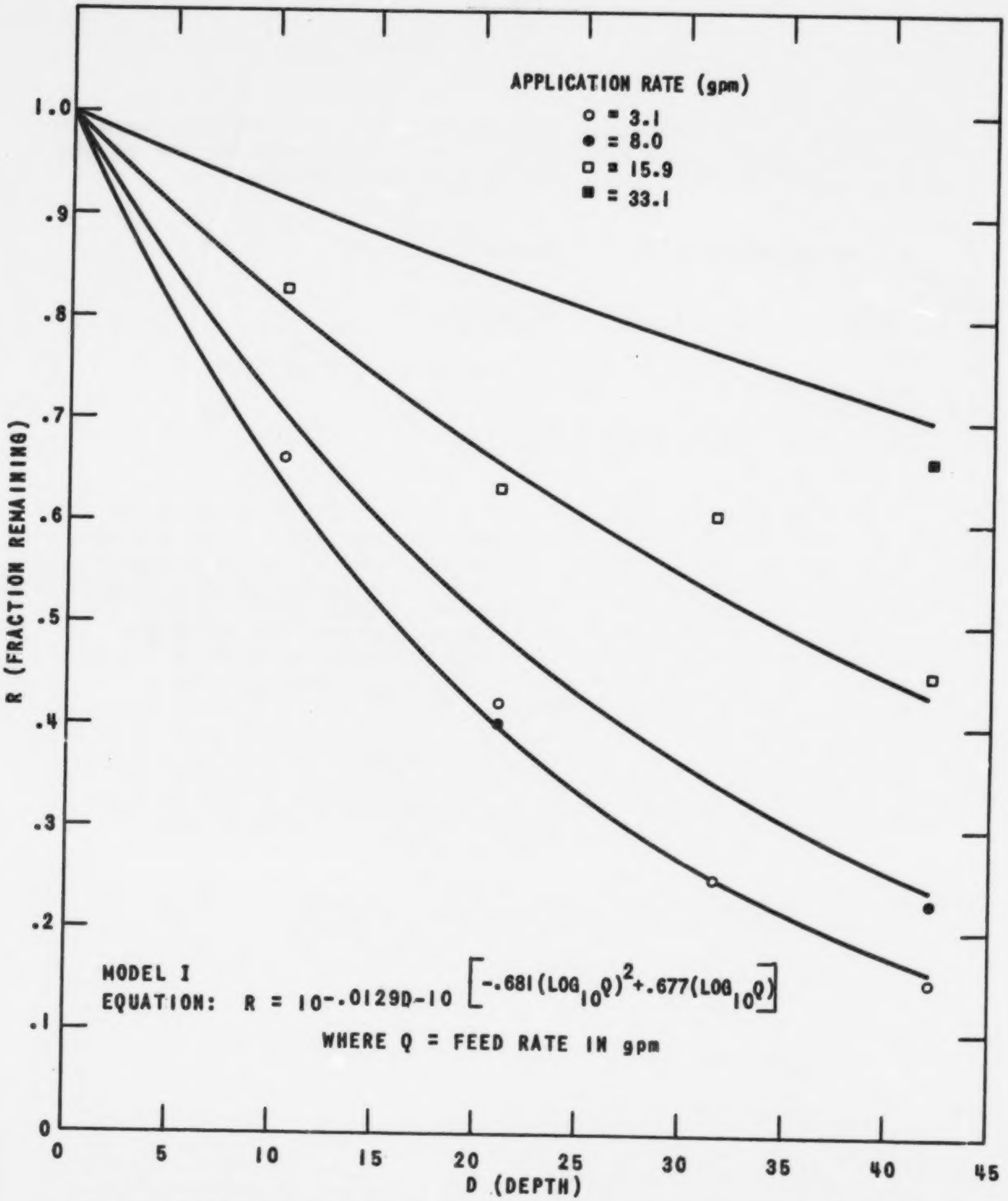
$$y = -0.681x^2 + 0.677x - 1.890 + \log D$$

or in terms of the original variables:

$$R = 10^{-0.0129D \cdot 10}\left[-0.681(\log_{10}Q)^2 + 0.677(\log_{10}Q)\right]$$

(Equation: Model I - Figure 16)

While Equation Model I represents the actual field data quite well over the ranges of "D" and "Q" tested, it was felt that its complex form and obviously empirical nature make it an unreliable predictor of the efficiency of filters with depth-loading combinations not actually field-tested. Nevertheless, this fitted curve is shown in Figure 16 on a plot of R-values, where the R-values plotted were determined by converting averages of from 12 to 48 replicate values of the variable, $y = \log_{10}(-\log_{10}R)$, into corresponding "average" R-values.



RELATIONSHIP OF FRACTION-BOD-REMAINING TO DEPTH: THEORETICAL CURVES GIVEN BY MATHEMATICAL MODEL I FITTED TO OBSERVED DATA (PLOTTED POINTS ARE MEANS OF REPLICATE RUNS)

Figure 16

Model II. At a given hydraulic application rate, observed R-values plotted as a function of "D". This suggested the "logistic" function, an S-shaped curve. The particular form of the logistic:

$$R = \frac{1}{1 + e^{(c + B \log_e D)}} = \frac{1}{1 + kD^B}$$

where $k = e^c$

and c, and B are constants, was tried because it has desirable boundary conditions.

The above equation can be derived from the differential equation:

$$\frac{dR}{dD} = \frac{BR(1-R)}{D}$$

where "B" is a constant of proportionality.

The differential equation is appealing, because it makes the rate of BOD-removal proportional not only to "R", a measure of the amount of organic material available to be removed, but also to (1-R), the relative amount of growth-promoting BOD-reduction already effected on the upper portions of the filter. This is analogous to an autocatalytic-type reaction, where the initial rate of reaction is slow at first but accelerates to a maximum rate reached when an optimum balance exists between concentrations of the reactant and product-catalyst, after which the rate of reaction decreases.

Also, B/D, the constant of proportionality at a given depth, is smaller at deeper depths than at shallow depths, so that the strength of the dependence of dR/dD on the product R(1-R) decreases as depth increases.

The relationship, $R = \frac{1}{1 + kD^B}$, was linearized as follows:

$$y = \log_{10} (\frac{1-R}{R})$$

$$= \log_{10}K + B \log_{10}D = a + Bx,$$

where $x = \log_{10}D$

The resulting linear model was fitted by the method of least-squares to each of the three sets of data for Q-values where samples had been taken at more than one depth. (At the 33.1 GPM application rate, samples were collected only at the 42 ft. depth.) The B-values (slopes) obtained were not significantly different from each other compared to the experimental error, so that it was decided to use the same slope for all Q-values.

The three intercepts were not a linear function of "Q", therefore it was considered desirable to include a fourth point in a plot of "a" versus "Q" to better determine the form in which "Q" should enter the equation. Mean values of "y" were plotted as a function of log Q using all data collected at the 42-foot depth. They were found to plot approximately linearly. Therefore, a term, C $\log_{10}Q$, was introduced as a "spacer" to separate the "y" versus "x" curves between the various Q-values.

The model:

$$y = a + Bx + Cz$$

where $z = \log_{10}Q$

was fitted to the data by the method of least squares, yielding the result:

$$y = -1.219 + 1.459x - 0.840z$$

In the original variables the equation had the following form:

$$\frac{1-R}{R} = 0.0605\ D^{1.459}\ Q^{-0.840}$$

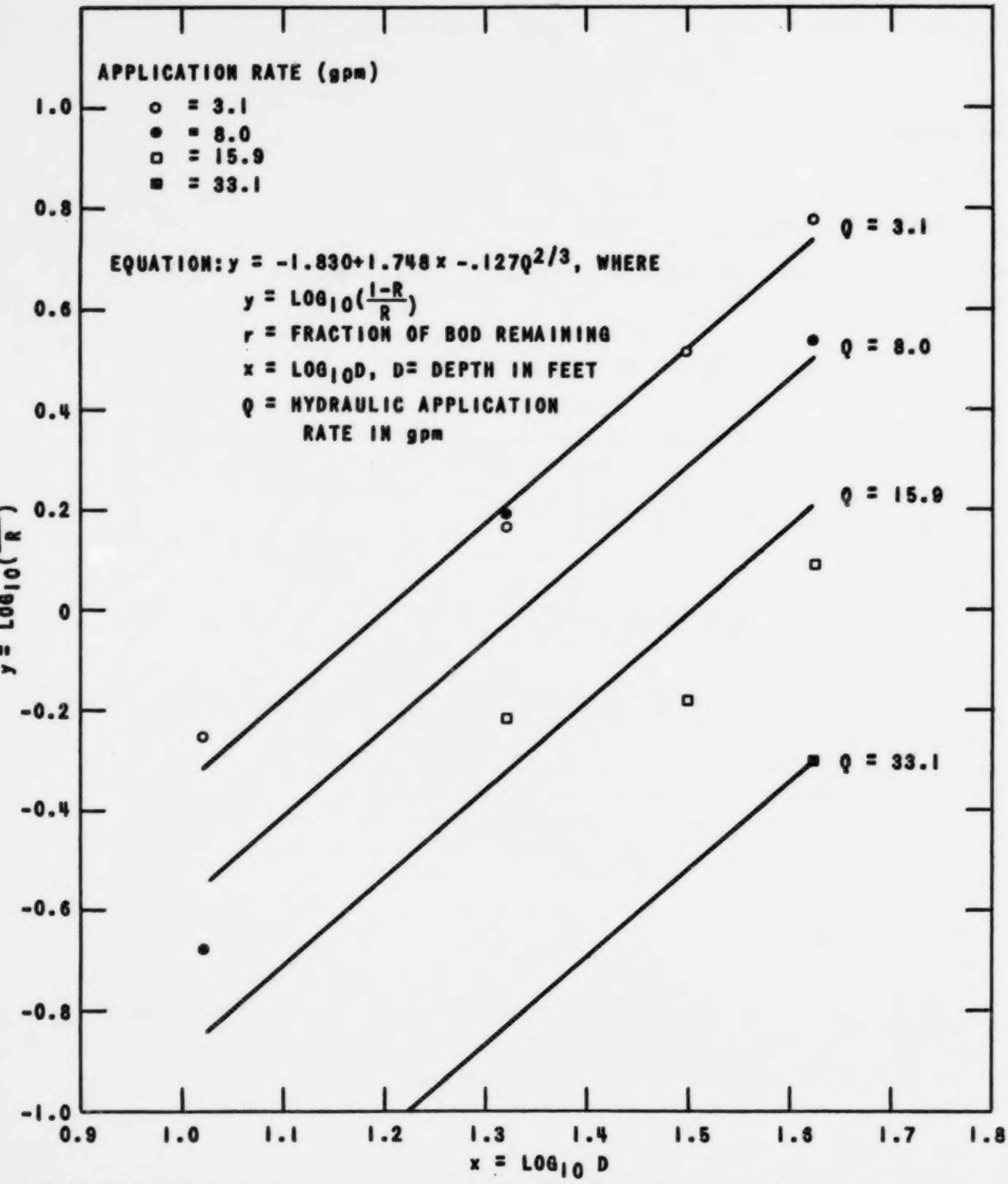
$$\text{or } R = \frac{1}{1 + 0.0605\ D^{1.459}Q^{-0.840}}$$

However, this equation did not give the proper spacing between the curves corresponding to different values of "Q". Therefore, a more general expression, $w = Q^p$, was substituted for $z = \log_{10}Q$ and various values of "p" were compared by trial and error to find a value which would give the best spacing between "R" versus "D" curves for the different Q-values. The exponent, $p = 2/3$, was so close to the best-fit value of "p" that it was decided to use $w = Q^{2/3}$ in the model equation:

$$y = a + Bx + w.$$

Fitting the model to the data by the method of least squares gave the following equation:

$$y = -1.830 + 1.748x - 0.127w \qquad \text{(Figure 17)}$$



LEAST-SQUARES FIT OF A LINEAR TRANSFORM OF MODEL II TO OBSERVED FRACTIONS BOD-REMAINING AT GIVEN DEPTHS

(PLOTTED POINTS ARE MEANS OF REPLICATE RUNS)

Figure 17

In the original variables, the equation appears as follows:

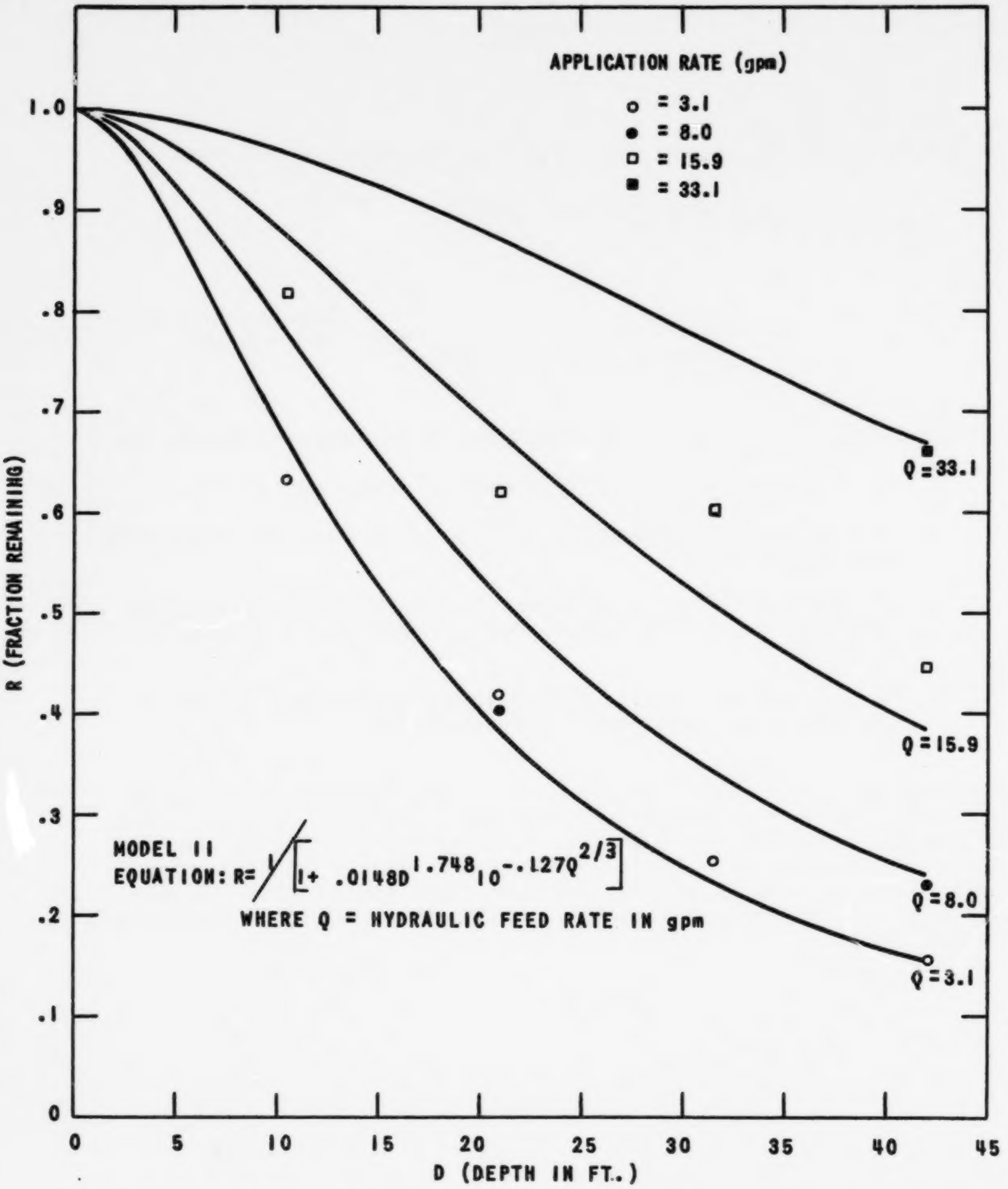
$$\frac{1-R}{R} = 0.0148\ D^{1.748}\ 10^{-0.127\ Q^{2/3}}$$

or: $$R = \frac{1}{1 + 0.0148\ D^{1.748}\ 10^{-0.127\ Q^{2/3}}}$$ (Equation Model II - Figure 18)

The following should be noted with regard to Equation Model II:

1. For a depth of zero, the fraction remaining is one.
2. As the depth approaches infinity, the fraction remaining approaches zero.
3. As the hydraulic application rate approaches zero, the fraction remaining approaches a limit which is dependent on depth.
4. As the hydraulic application rate approaches infinity, the fraction remaining approaches one.

Equation Model II indicates a limit to the removal that can be obtained on any finite increment of depth or unit of media; but with infinite depth, a condition that provides infinite contact time, all measurable BOD will be removed. While this is considered plausible, it is not recommended that application of this equation be made to loadings out of the range of those observed in this study.



RELATIONSHIP OF FRACTION-BOD-REMAINING TO DEPTH: THEORETICAL CURVES GIVEN BY MATHEMATICAL MODEL III FITTED TO OBSERVED DATA (PLOTTED POINTS ARE AVERAGES OF REPLICATE RUNS)

Figure 18

Equation Model II represents the data adequately in that means of replicate R-values for the different sets of experimental conditions deviate randomly from the fitted curves and not systematically. There is, however, an indication that the reliability of the equation as a predictor of BOD-removal is less at low hydraulic application rates and at shallow depths than at high hydraulic application rates and deeper depths. This is not caused by poorer fit of the equation under these conditions, but rather by greater variability in the data. Standard deviations of replicate R-values are listed in Table 10.

Although 5 of the 11 means of R-values from replicate runs differ significantly from predicted values given by the Model II equation, they differ by amounts small in comparison with the inconsistent efficiency of the pilot plant. Even for the largest bias, where the estimated R-value of 0.52 was 0.11 units higher than the observed mean R-value of 0.40, in 3 out of 14 sampling periods, efficiencies were higher than 0.52. The equation presented is itself only an estimated relationship from a relatively small amount of data. Small biases might disappear if better estimates of the parameters of the equation were obtained from additional data.

Table 11 shows a comparison of the predictions obtained with the Model I and Model II equations. It can be seen that agreement, within the range of loadings and depths studied, is reasonably good.

Table 10

Model II Equation
Observed Averages versus Fitted Curve

Q (gpm)	D (feet)	n	$\bar{R}$	R'	Bias ($\bar{R} - R'$)	95% Confidence Limits for True Bias	σ_R
3.1	10.5	15	0.63	0.67	N.S.	-0.15 to 0.07	0.20
3.1	21.0	17	0.42	0.38	N.S.	-0.05 to 0.12	0.16
3.1	31.5	17	0.25	0.23	N.S.	-0.01 to 0.05	0.13
3.1	42.0	33	0.15	0.16	N.S.	-0.03 to 0.03	0.08
8.0	21.0	14	0.40	0.52	-0.11	-0.18 to -0.04	0.13
8.0	42.0	29	0.23	0.24	N.S.	-0.02 to 0.04	0.07
15.9	10.5	13	0.82	0.88	-0.06	-0.10 to -0.02	0.07
15.9	21.0	24	0.62	0.68	-0.06	-0.11 to -0.01	0.12
15.9	31.5	13	0.60	0.51	0.09	0.04 to 0.15	0.10
15.9	42.0	48	0.45	0.38	0.06	0.03 to 0.10	0.12
33.1	42.0	12	0.66	0.67	N.S.	-0.04 to 0.03	0.06

Symbols used in Table 10:

Q - Hydraulic Application Rate in Gallons per minute.

D - Sampling Depth in Feet.

n - Number of Sampling periods.

$\bar{R}$ - Average of "n" R-values, where R is the fraction of BOD remaining determined from a single sampling period.

R'- Predicted fraction BOD Remaining, using the equation:

(Model II)

$$\frac{1 - R'}{R'} = 0.0148\, D^{1.748}\, 10^{-0.127Q^{2/3}}$$

95% Confidence Limits - Confidence limits for the amount by which the equation underestimates or overestimates the long-term average BOD-removal efficiency of the Dowpac HCS unit at a given hydraulic application rate (Q), and sampled at a given depth (D).

N.S. - Not significantly different from zero at the 5% probability level.

σ_R - Standard deviation of R-values from replicate sampling periods.

Table 11

Depths in Feet Required to Provide Various Mean Fractions of BOD Remaining at Various Hydraulic Loadings as Predicted by Model I and II Equations

(R) Fraction Remaining	Model Equation	Hydraulic Loading** 20 MGAD (3.1 GPM)	50 MGAD (7.8 GPM)	200 MGAD (31.1 GPM)
R = 0.20	I	36.8	47.0*	174*
(80% Removal)	II	35.1	47.5*	128*
R = 0.50	I	15.9	20.3	75.2*
(50% Removal)	II	15.9	21.5	57.8*
R = 0.80	I	5.1	6.5	24.2
(20% Removal)	II	7.0	9.7	26.1

Notes:

*Outside Range of Depths Studied.

**Loadings in MGAD are based upon the assumption that sewage was applied to the entire square pilot plant tower (37-1/2" x 37-1/2" = 9.77 ft.^{2} in area), A rotary distributor, 36" in diameter was actually used. By visual observation at intermediate sampling points, it was obvious that lateral movement of liquid brought appreciable, but undetermined, amounts of sewage into sections not receiving an initial proportionate amount of sewage.

Other Methods of Analysis

The following section on miscellaneous figures contains several other conventional representations of the data. Figures C-1 through C-5 show applied BOD and COD loads plotted against percent remaining for automatically collected samples. No curves are shown because it is not believed that the effects of organic and hydraulic loading could be compositely treated. Consequently such a curve would be misleading. Figures C-6 through C-10 show the relationship of total BOD load applied to total load removed. Equations shown were fitted by the method of least squares using data obtained by analysis of automatically collected samples. As previously noted, these Figures indicate a possibility that the fraction removed is independent of load applied for the range of loads studied. Figures C-11 through C-13 show the relationship of depth to percent remaining for manually collected samples. An equation of the form $R = 10^{-K'D}$ was fitted by the method of least squares to the data for each individual hydraulic loading. In these figures the wide-spread of data can be seen. Figures C-14 through C-17 show equations of the same form fitted by the method of least squares to BOD and COD data obtained by analysis of automatically collected samples. These data were collected at only the 42-foot depth. The curves were required to pass through fraction remaining equal to one and zero-depth. These equations assume a constant fraction of the remaining load is removed in each succeeding increment of depth and that all measurable load is removable. These assumptions, particularly with respect to chemical oxygen demand, are subject to question. Figures C-18 and C-19 show the relationship of hydraulic application rate to mean BOD and COD removals for automatically collected samples.

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C-3	Relationship of Per Cent Remaining to Applied BOD Load for Lab Settled Automatically Collected Samples at 42 Foot Depth with 1:1 Recirculation.
C-4	Relationship of Per Cent Remaining to Applied COD Load for Lab Settled Automatically Collected Samples at 42 Foot Depth.
C-5	Relationship of Per Cent Remaining to Applied COD Load for Tank Settled Automatically Collected Samples at 42 Foot Depth.
C-6	Relationship of BOD Applied to BOD Removed at a Hydraulic Rate of 3.1 gpm for Automatically Collected, Lab Settled, 8-Hour Composites at 42 Foot Depth.
C-7	Relationship of BOD Applied to BOD Removed at a Hydraulic Rate of 3.1 gpm for Automatically Collected, Lab Settled, 24-Hour Composites at 42 Foot Depth.
C-8	Relationship of BOD Applied to BOD Removed at a Hydraulic Rate of 8 gpm for Automatically Collected, Tank Settled, 24-Hour Composites at 42 Foot Depth.
C-9	Relationship of BOD Applied to BOD Removed at a Hydraulic Rate of 15.9 gpm for Automatically Collected, Tank Settled, 8-Hour Composites at 42 Foot Depth.
C-10	Relationship of BOD Applied to BOD Removed at a Hydraulic Rate of 33.1 gpm for Automatically Collected, Tank Settled, 8-Hour Composites at 42 Foot Depth.
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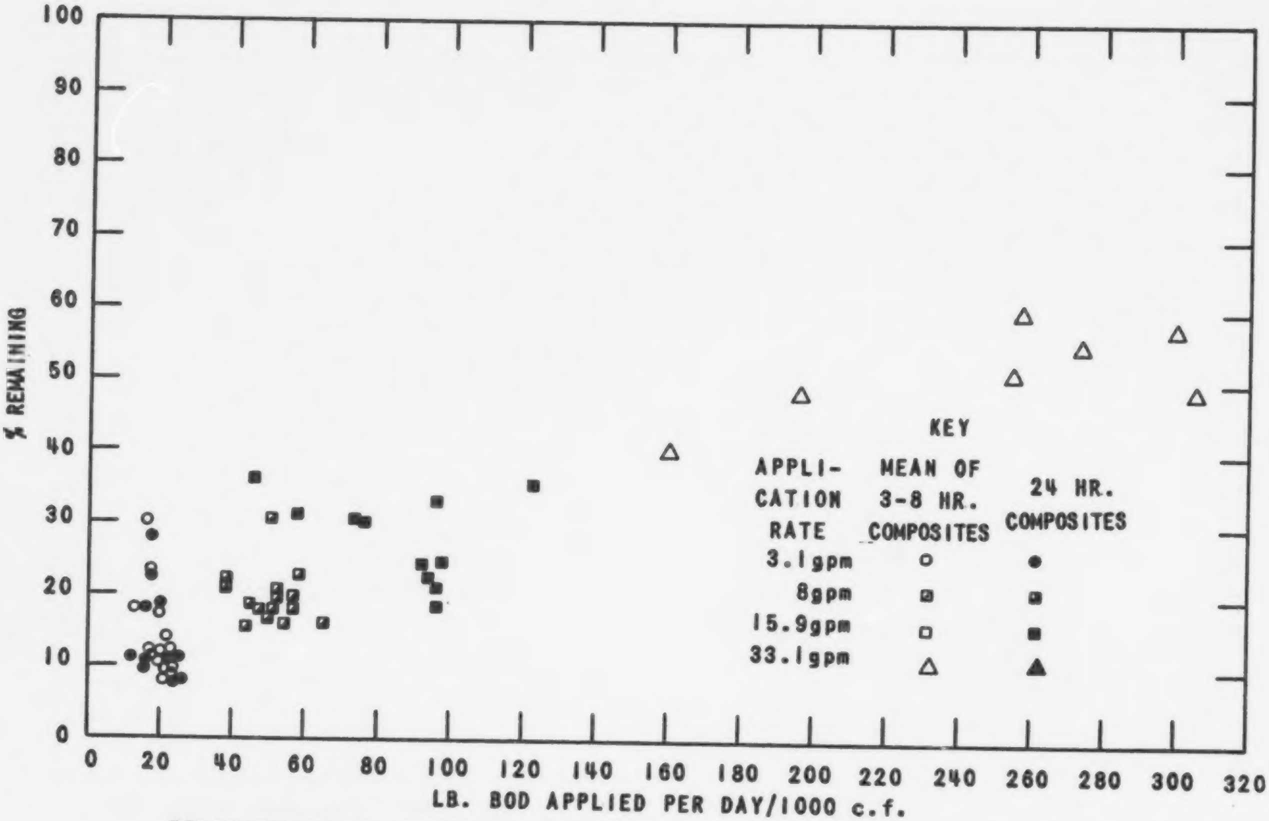
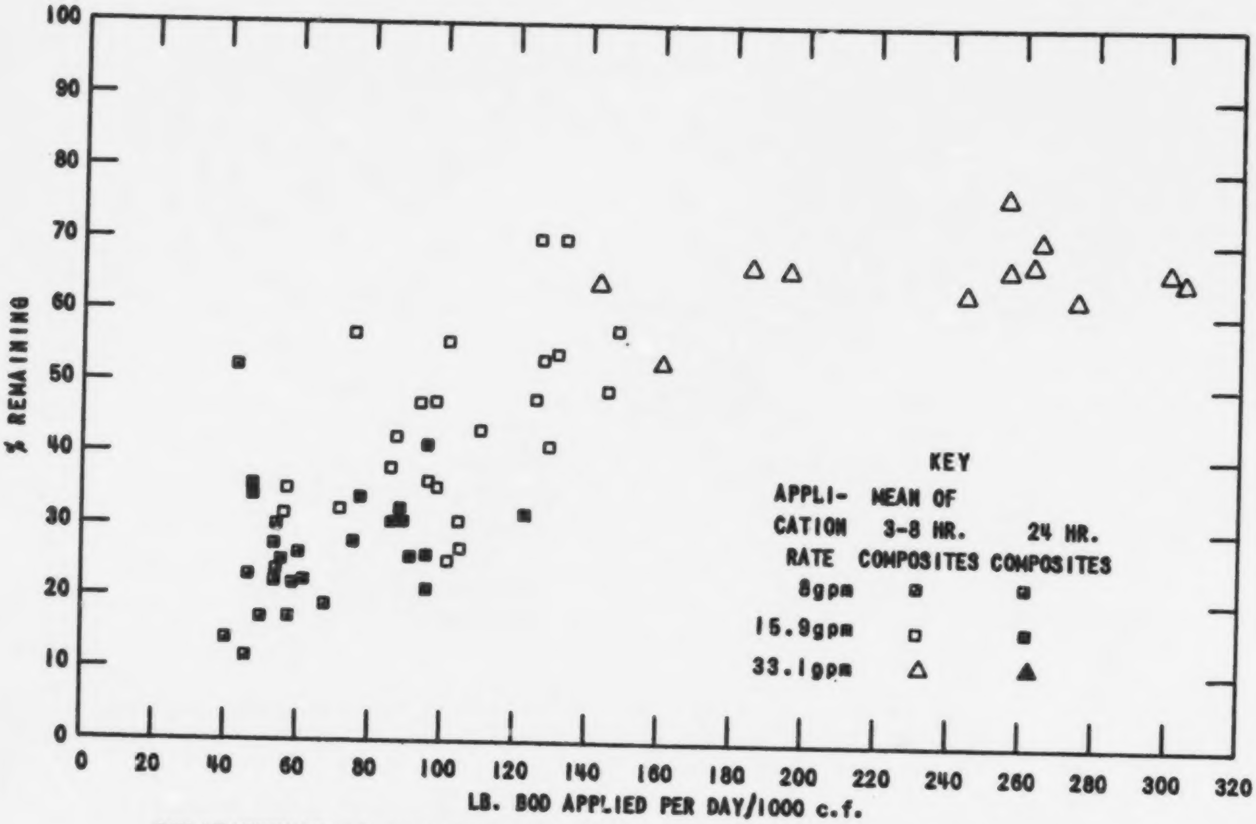
C-22	Observed Data at a Hydraulic Application Rate of 16 gpm Direct Plus 16 gpm Recirculation, March 20-April 8, 1956.
C-23	Observed Data at a Hydraulic Application Rate of 8.0 gpm, April 10-29, 1956.
C-24	Observed Data at a Hydraulic Application Rate of 3.1 gpm, June 11-27, 1956.



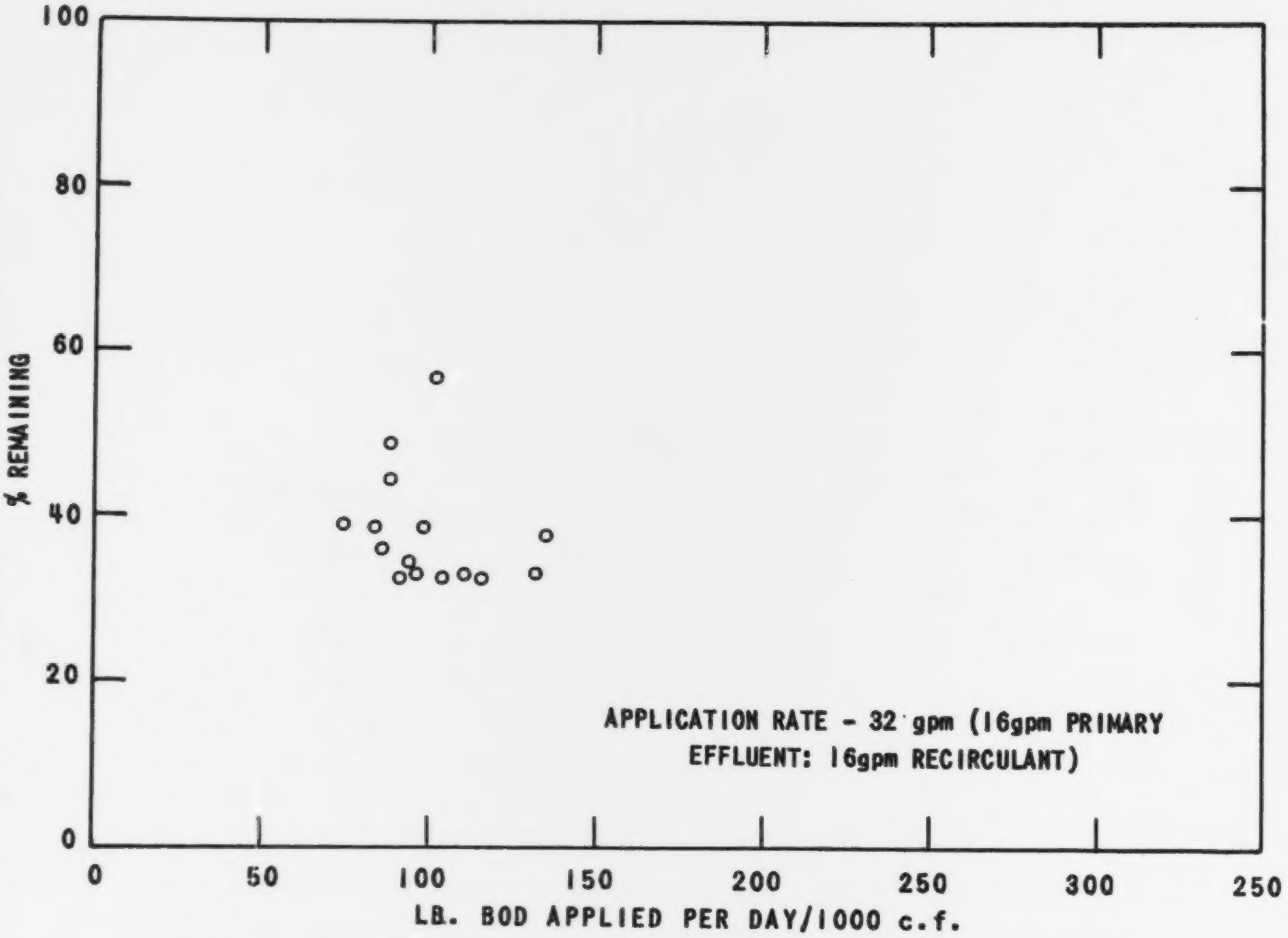
RELATIONSHIP OF PER CENT REMAINING TO APPLIED BOD LOAD FOR LAB SETTLED, AUTOMATICALLY COLLECTED SAMPLES AT 42 FOOT DEPTH

C-1



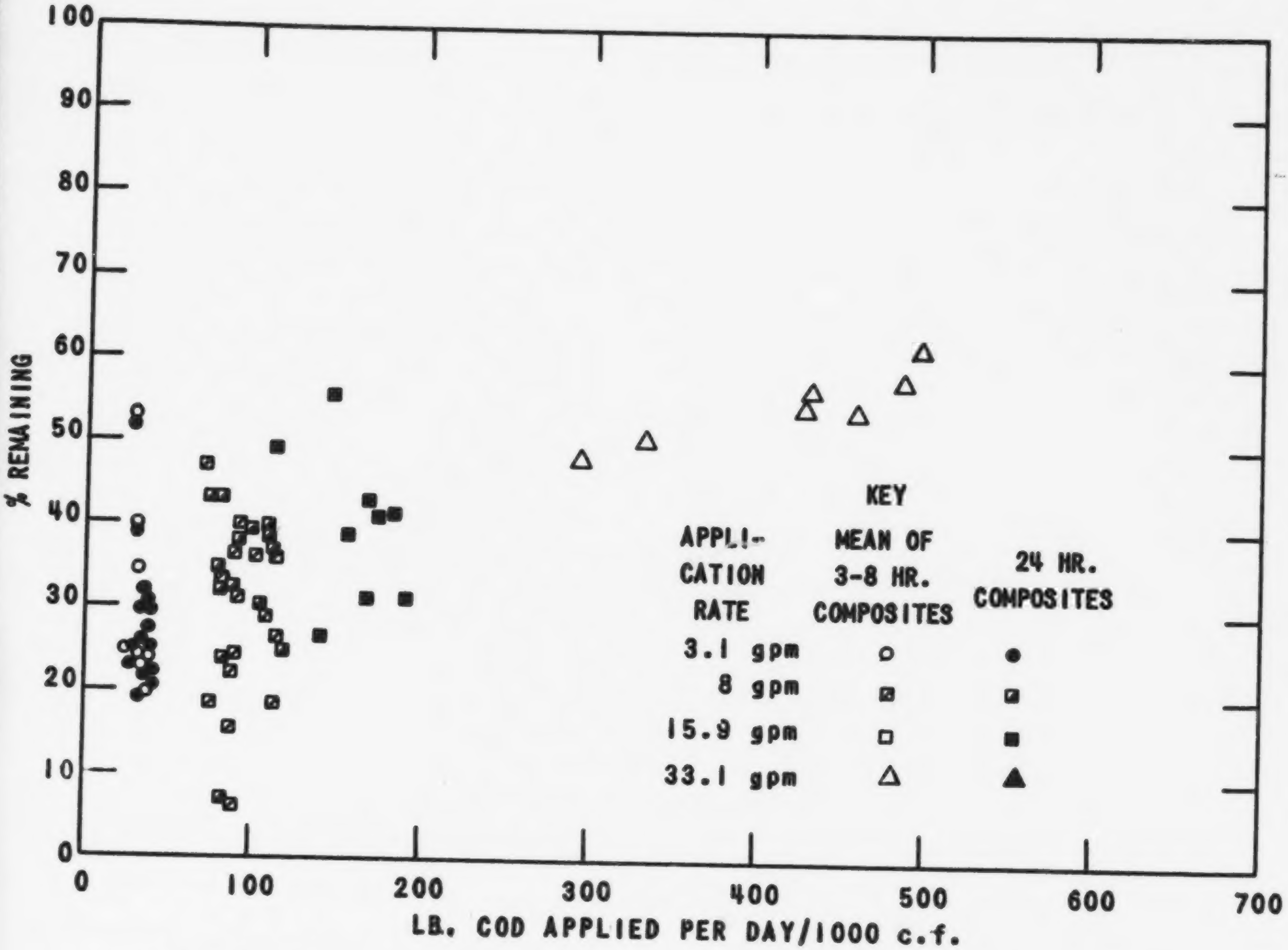
RELATIONSHIP OF PER CENT REMAINING TO APPLIED BOD LOAD FOR LAB SETTLED AUTOMATICALLY COLLECTED SAMPLES AT 42 FOOT DEPTH

C-2



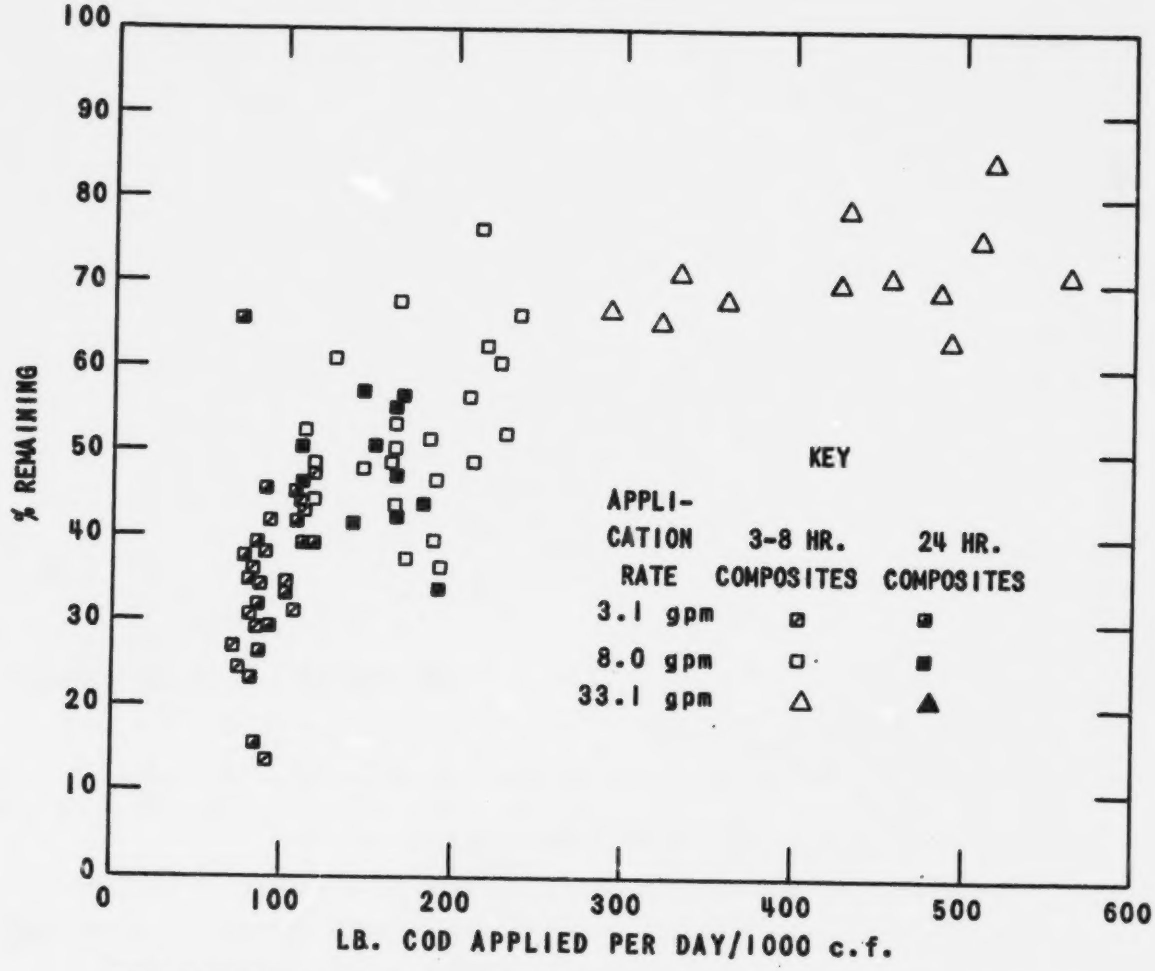
RELATIONSHIP OF PER CENT REMAINING TO APPLIED BOD LOAD FOR LAB SETTLED, AUTOMATICALLY COLLECTED SAMPLES AT 42 FOOT DEPTH WITH 1:1 RECIRCULATION

C-3



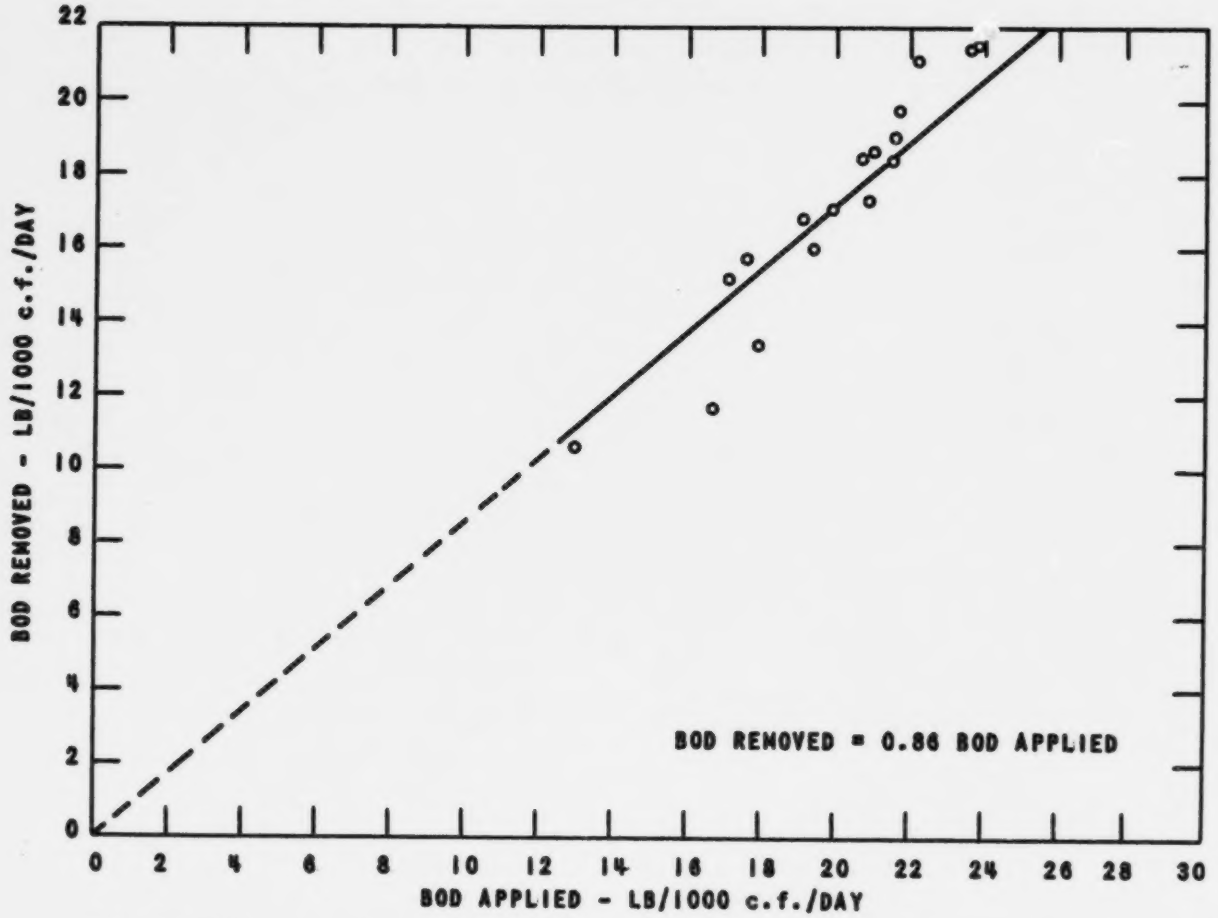
RELATIONSHIP OF PER CENT REMAINING TO APPLIED COD LOAD FOR LAB SETTLED AUTOMATICALLY COLLECTED SAMPLES AT 42 FOOT DEPTH

C-4



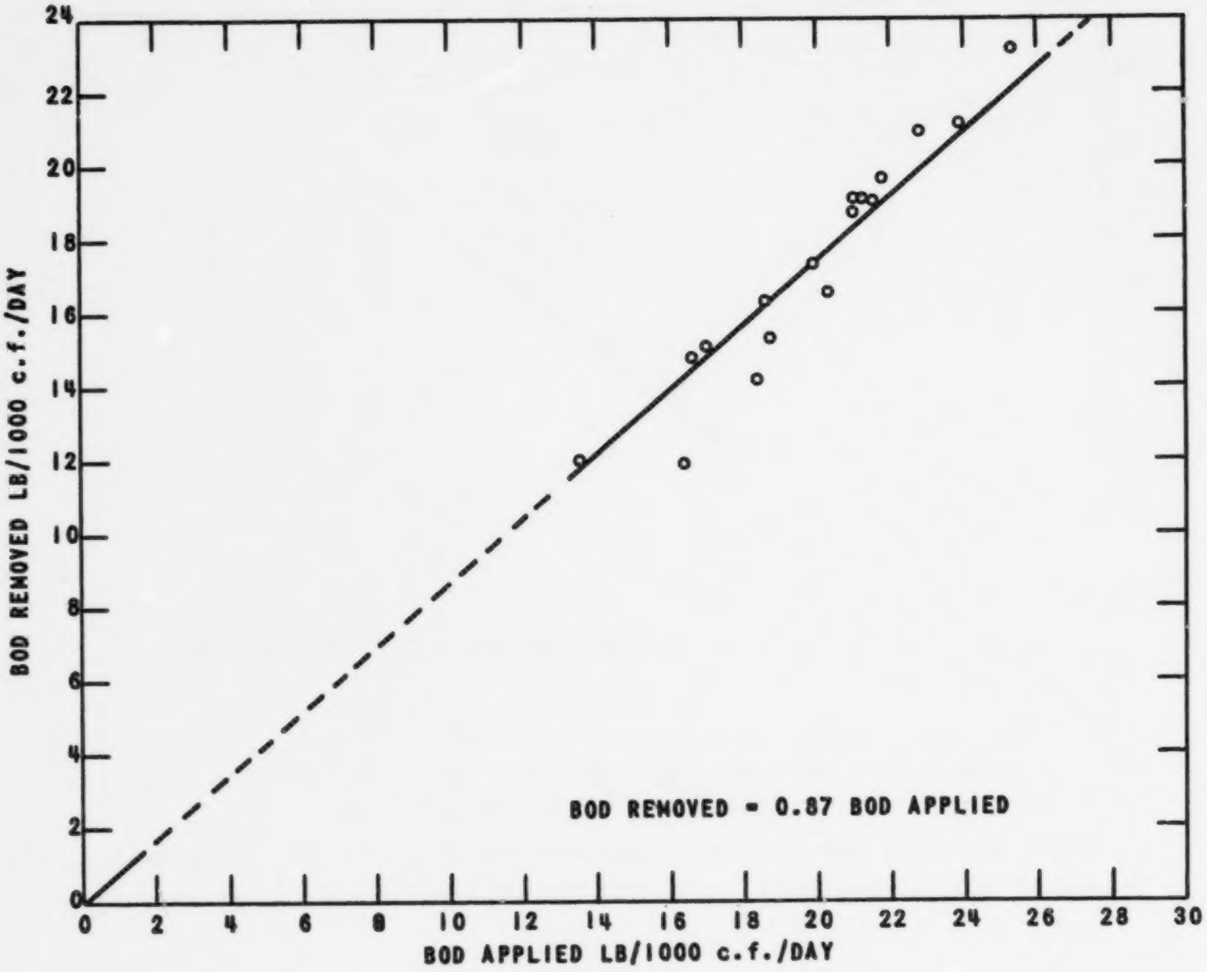
RELATIONSHIP OF PER CENT REMAINING TO APPLIED COD LOAD FOR TANK SETTLED AUTOMATICALLY COLLECTED SAMPLES AT 42 FOOT DEPTH

C-5



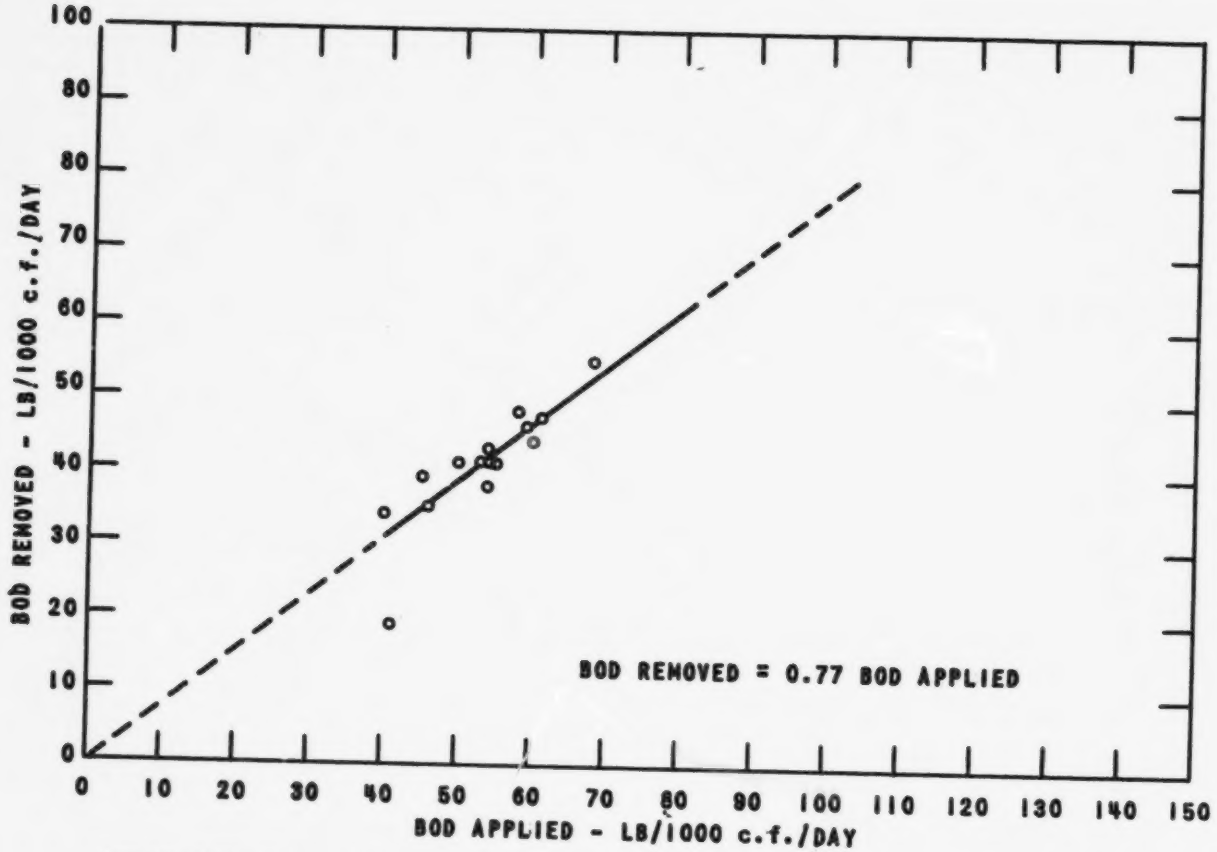
RELATIONSHIP OF BOD APPLIED TO BOD REMOVED AT A HYDRAULIC RATE OF 3.1 gpm, FOR AUTOMATICALLY COLLECTED, LAB SETTLED, 8-HOUR COMPOSITES AT 42 FOOT DEPTH

C-6



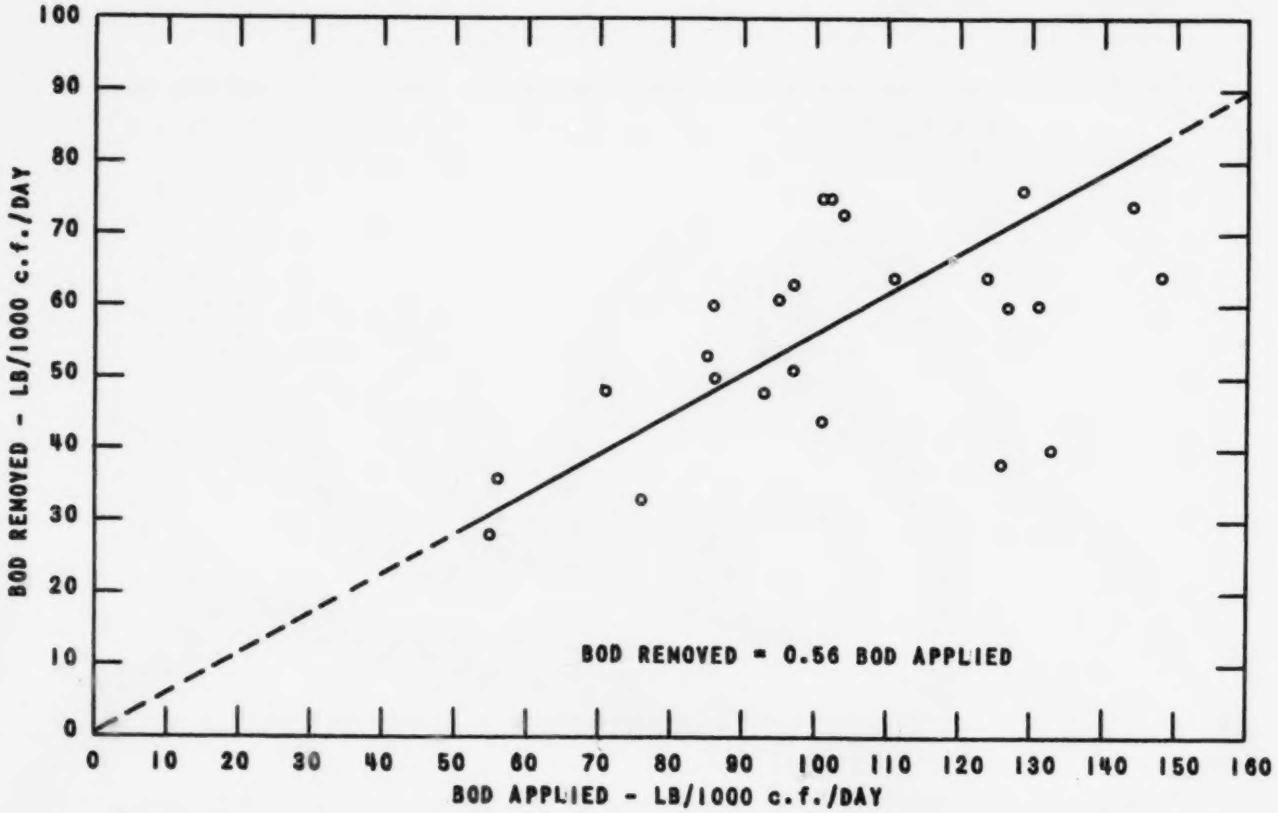
RELATIONSHIP OF BOD APPLIED TO BOD REMOVED AT A HYDRAULIC RATE OF 3.1 gpm
FOR AUTOMATICALLY COLLECTED, LAB SETTLED, 24 HOUR COMPOSITES AT 42 FOOT DEPTH

C-7



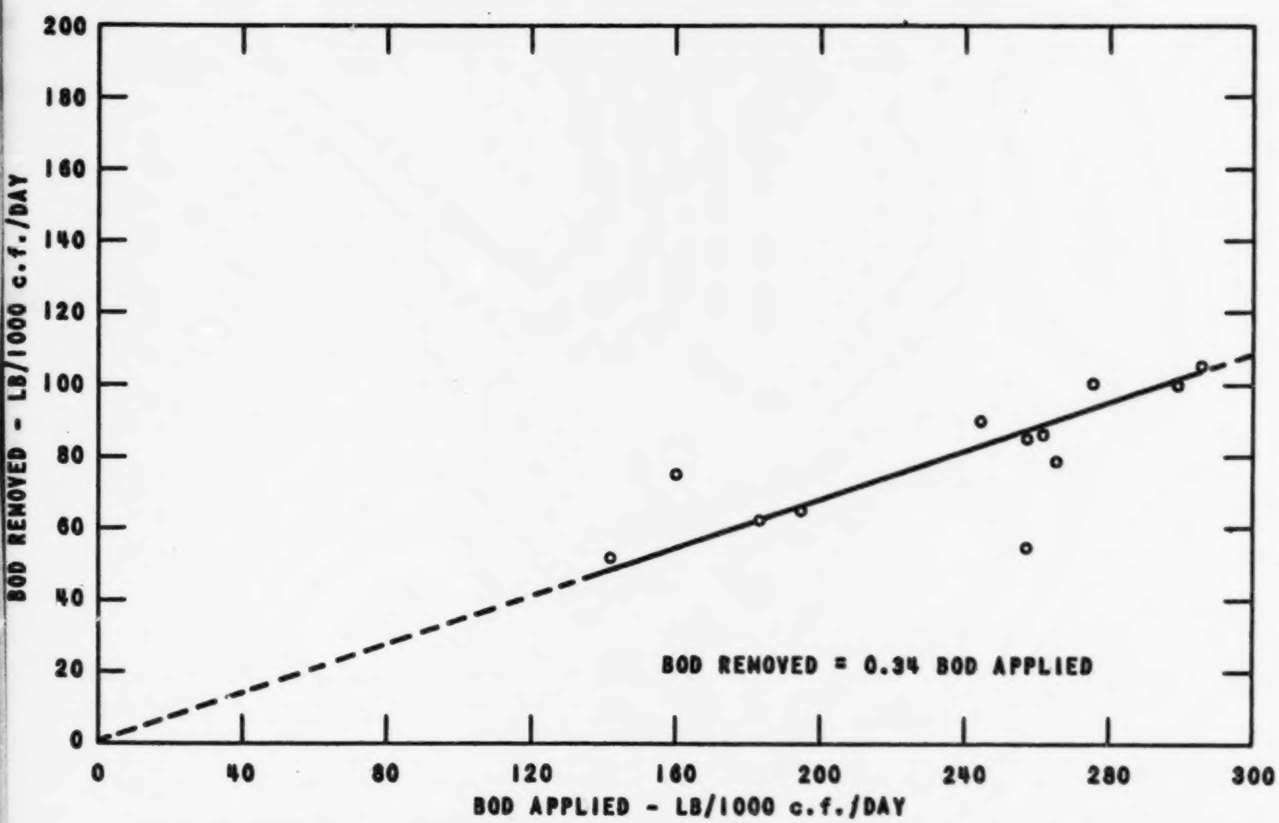
RELATIONSHIP OF BOD APPLIED TO BOD REMOVED AT A HYDRAULIC RATE OF 8gpm FOR AUTOMATICALLY COLLECTED, TANK SETTLED, 24 HOUR COMPOSITES AT 42 FOOT DEPTH

C-8



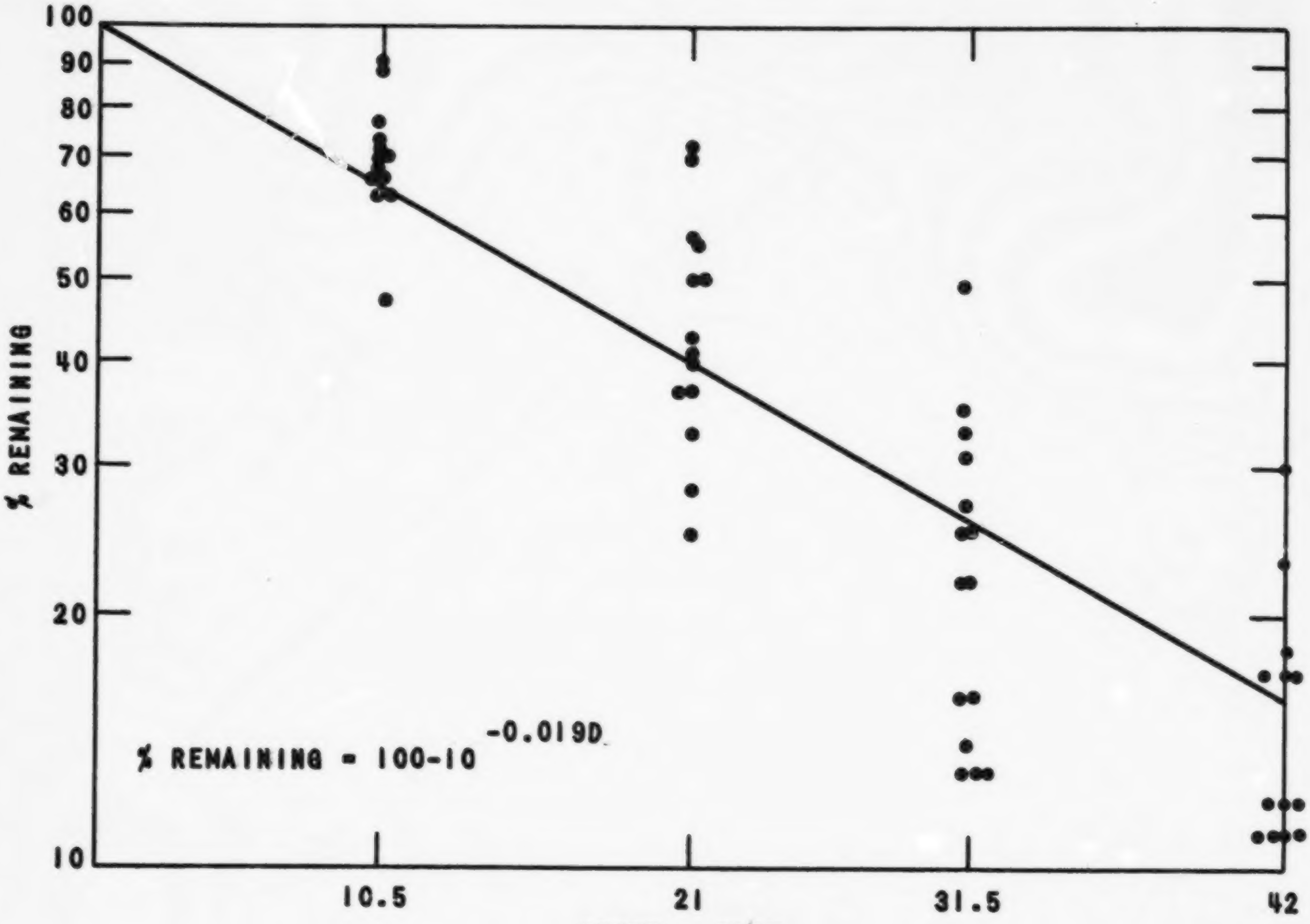
RELATIONSHIP OF BOD APPLIED TO BOD REMOVED AT A HYDRAULIC RATE OF 15.9gpm FOR AUTOMATICALLY COLLECTED, TANK SETTLED, 8 HOUR COMPOSITES AT 42 FOOT DEPTH

C-9



RELATIONSHIP OF BOD APPLIED TO BOD REMOVED AT A HYDRAULIC RATE OF 33.1gpm FOR AUTOMATICALLY COLLECTED, TANK SETTLED, 8 HOUR COMPOSITES AT 42 FOOT DEPTH

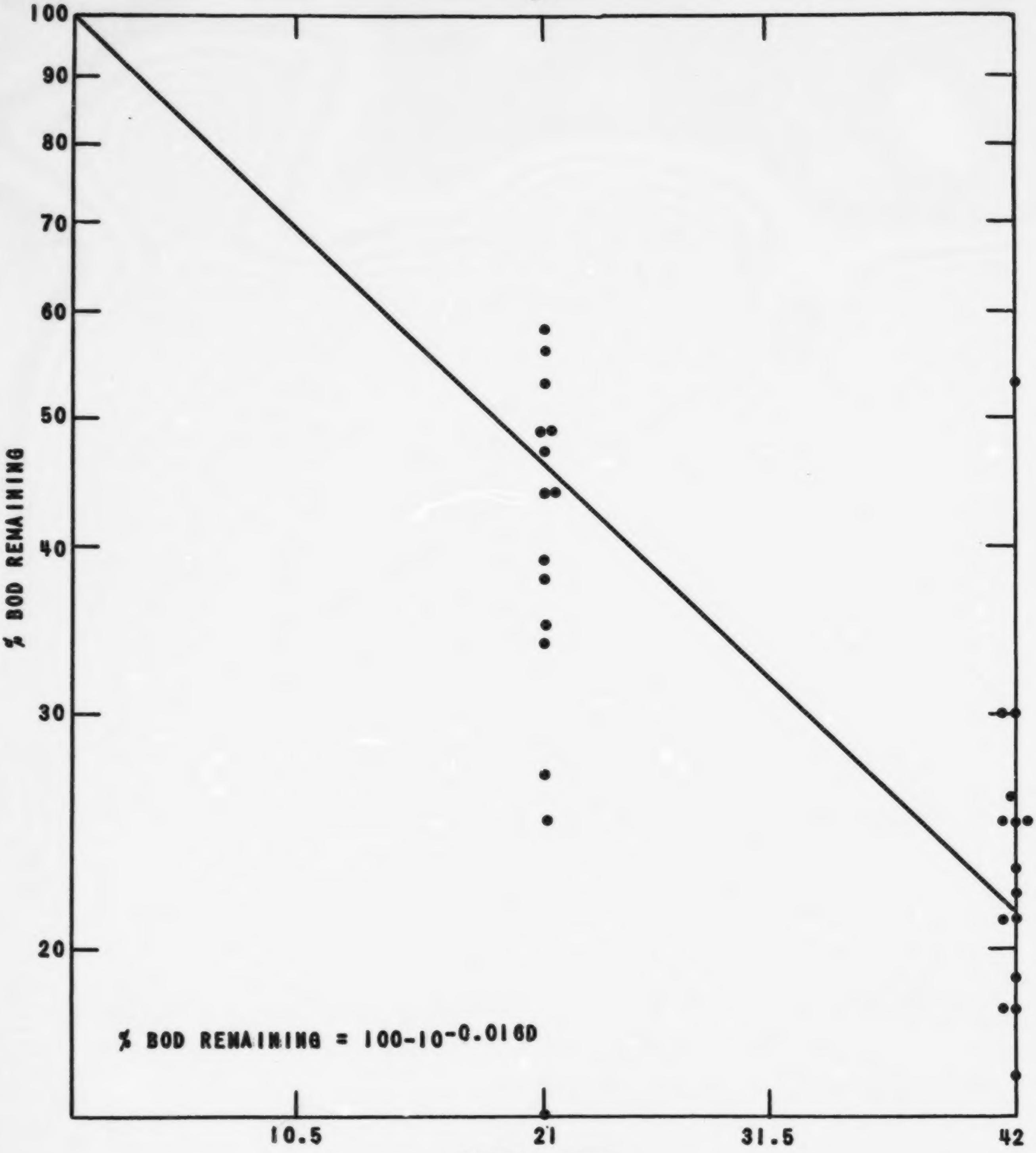
C-10



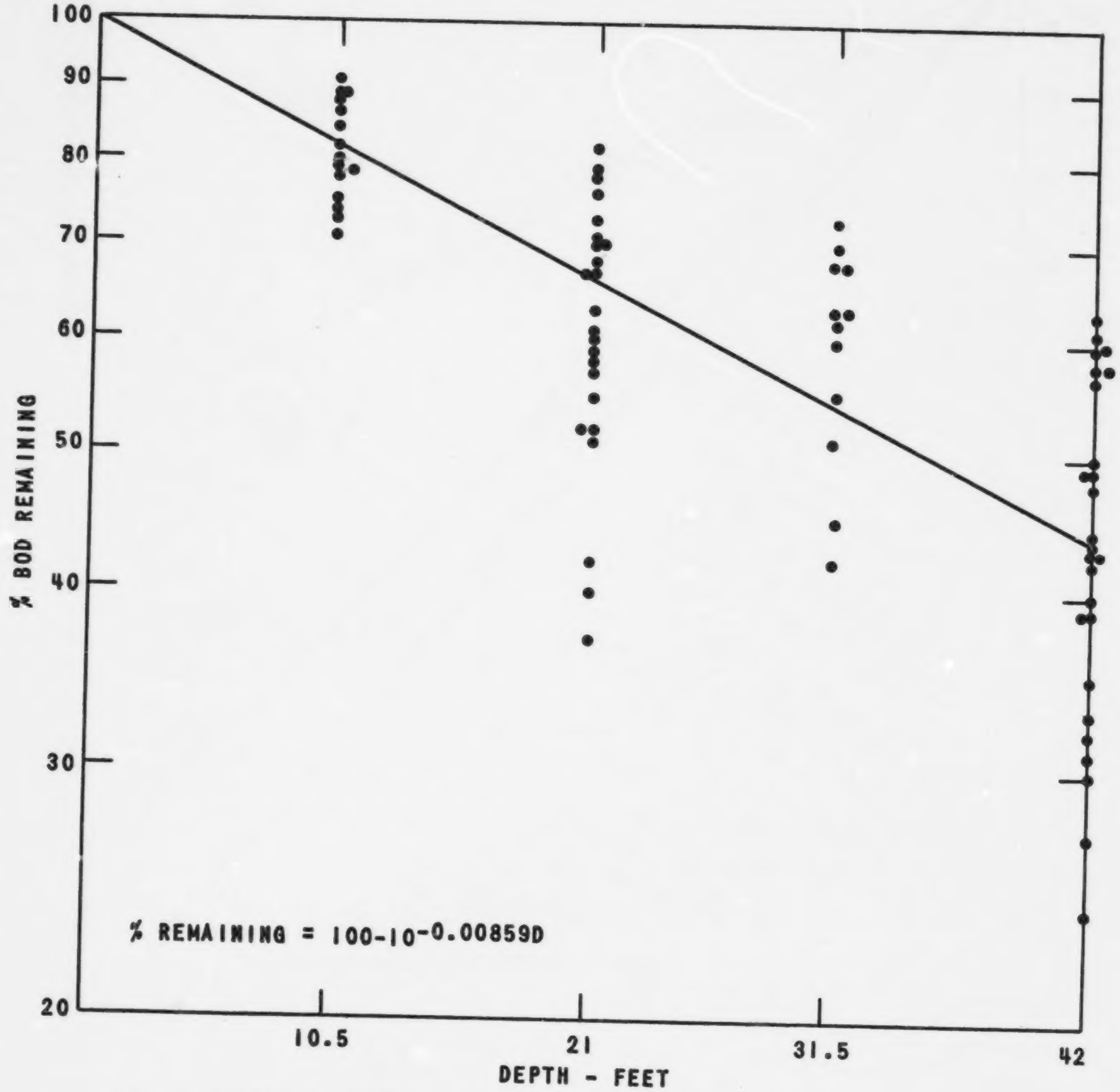
RELATIONSHIP OF DEPTH TO % BOD REMAINING FOR MANUALLY COLLECTED, LAB SETTLED SAMPLES AT A HYDRAULIC RATE OF 3.1gpm*

*DATA FOR JUNE 11, 12, 16, 18 OMITTED

C-11

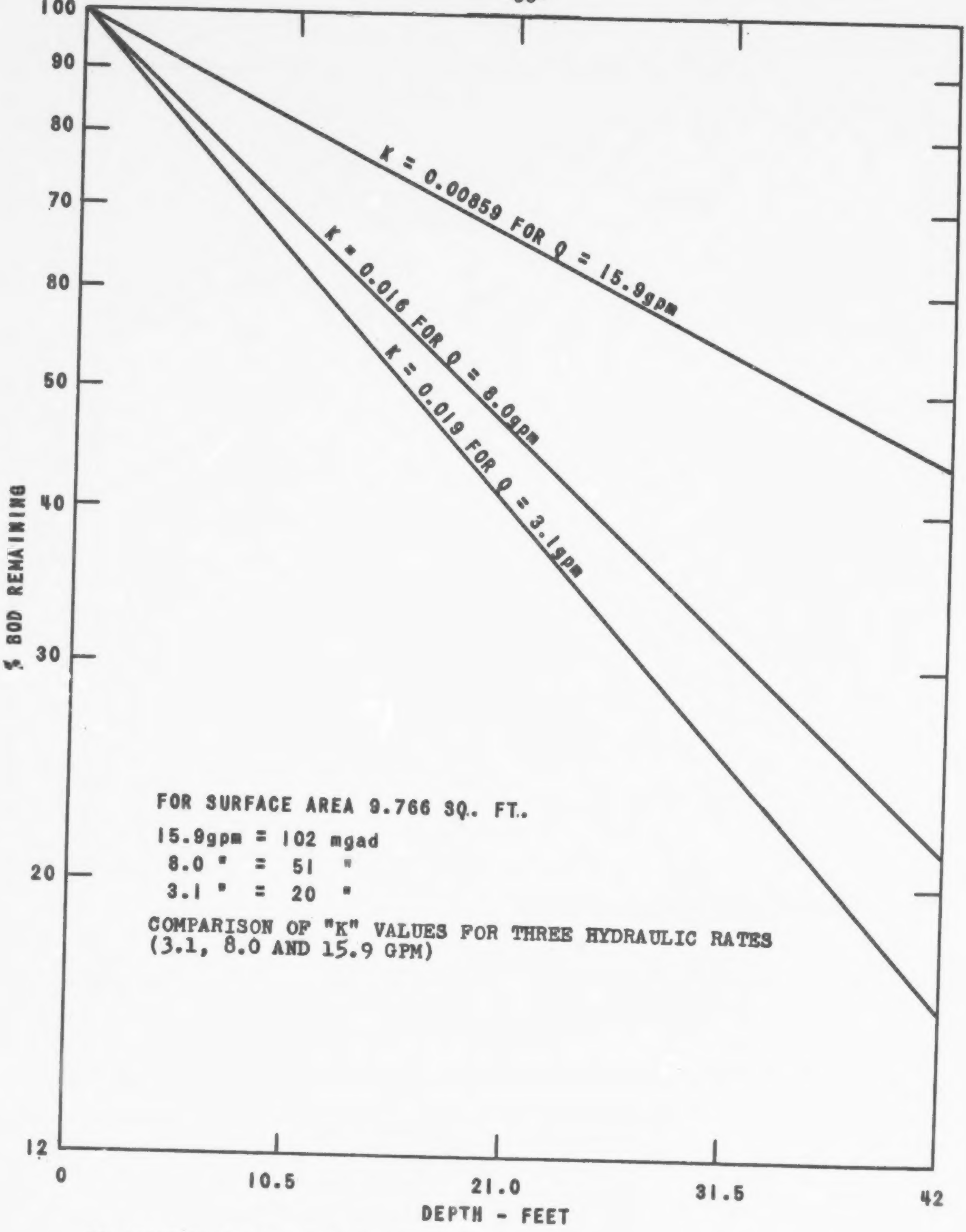


RELATIONSHIP OF DEPTH TO % BOD REMAINING FOR MANUALLY COLLECTED, LAB SETTLED SAMPLES AT A HYDRAULIC RATE OF 8gpm



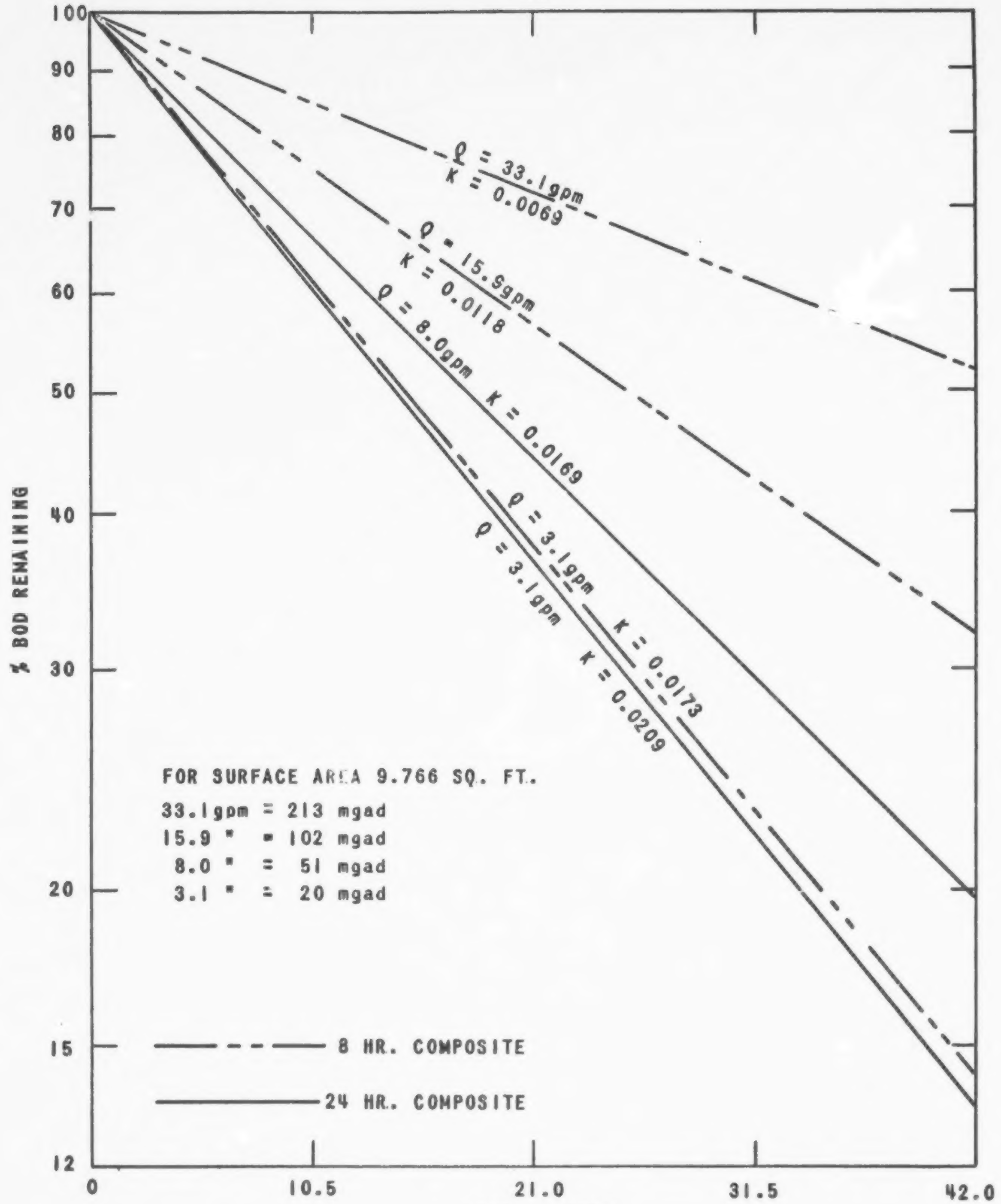
RELATIONSHIP OF DEPTH TO % BOD REMAINING FOR MANUALLY COLLECTED, LAB SETTLED SAMPLES AT A HYDRAULIC RATE OF 15.9gpm

C-13



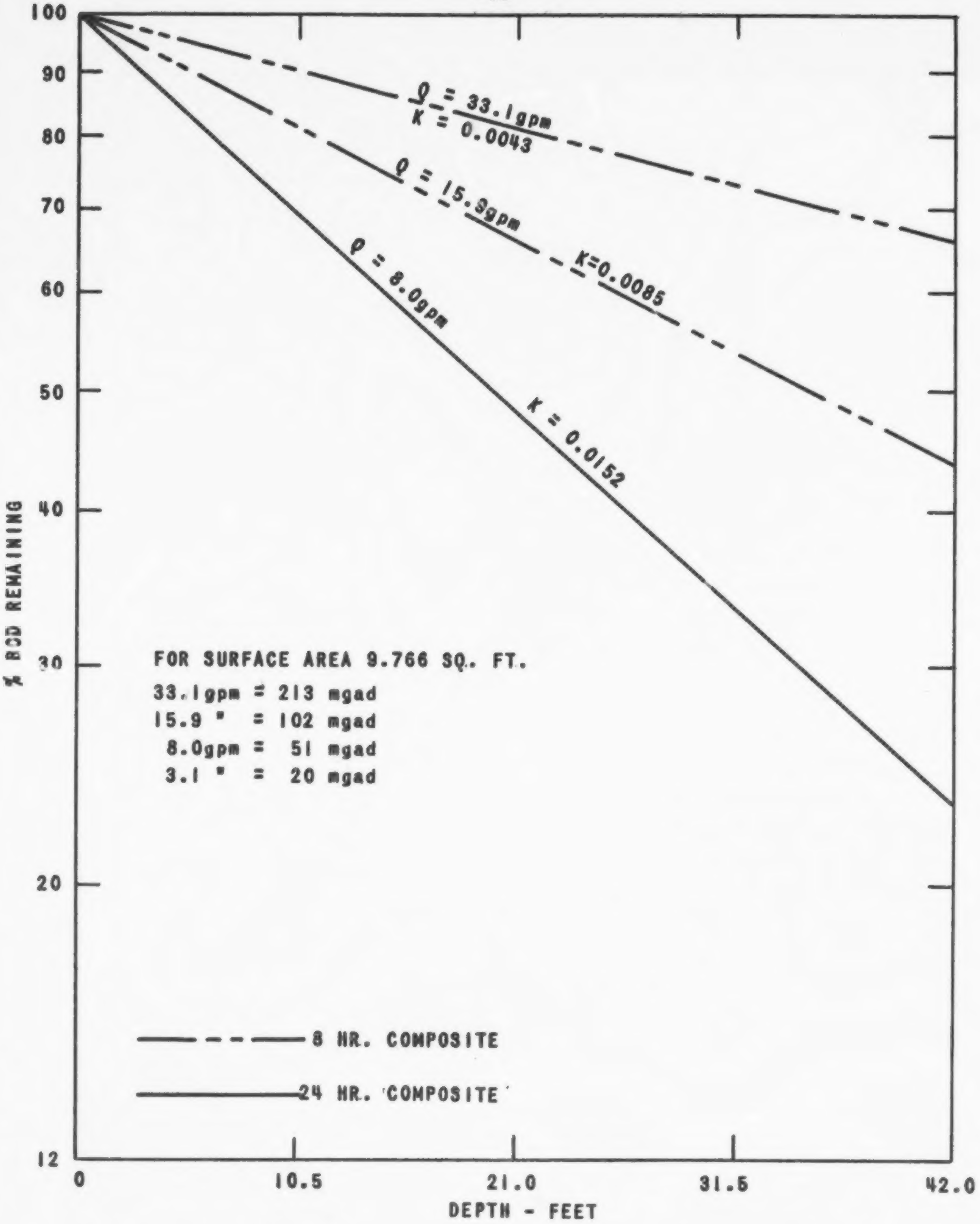
RELATIONSHIP OF % BOD REMAINING TO DEPTH FOR MANUALLY COLLECTED, LAB SETTLED SAMPLES

Figure C-13A



RELATIONSHIP OF DEPTH TO % BOD REMAINING FOR AUTOMATICALLY COLLECTED LABORATORY SETTLED SAMPLES BASED ON 42 FOOT DEPTH SAMPLES

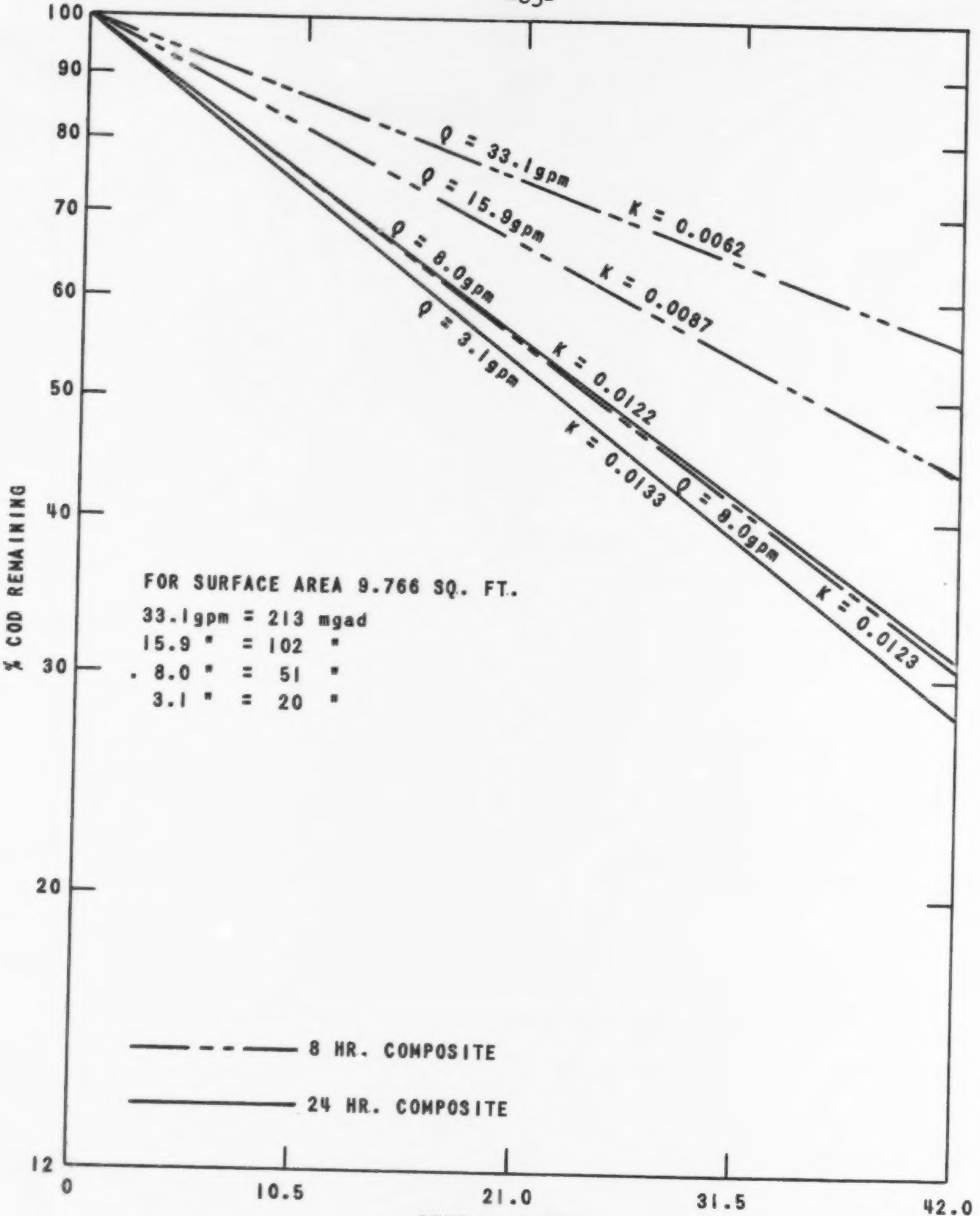
IF % REMAINING = $100-10^{-KD}$



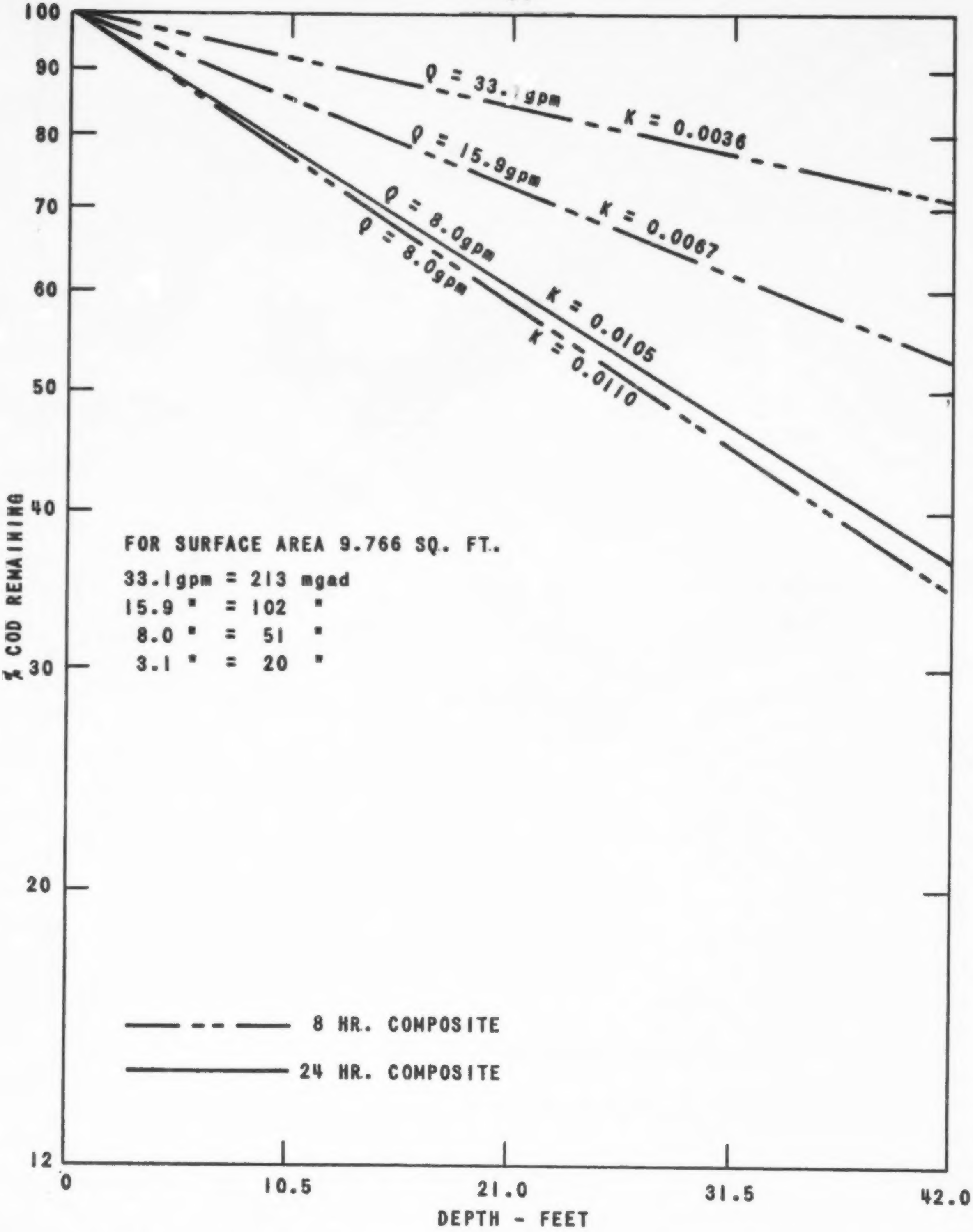
RELATIONSHIP OF % BOD REMAINING TO DEPTH FOR AUTOMATICALLY COLLECTED TANK SETTLED SAMPLES BASED ON 42 FOOT DEPTH SAMPLES IF

% REMAINING = $100 - 10^{-KD}$

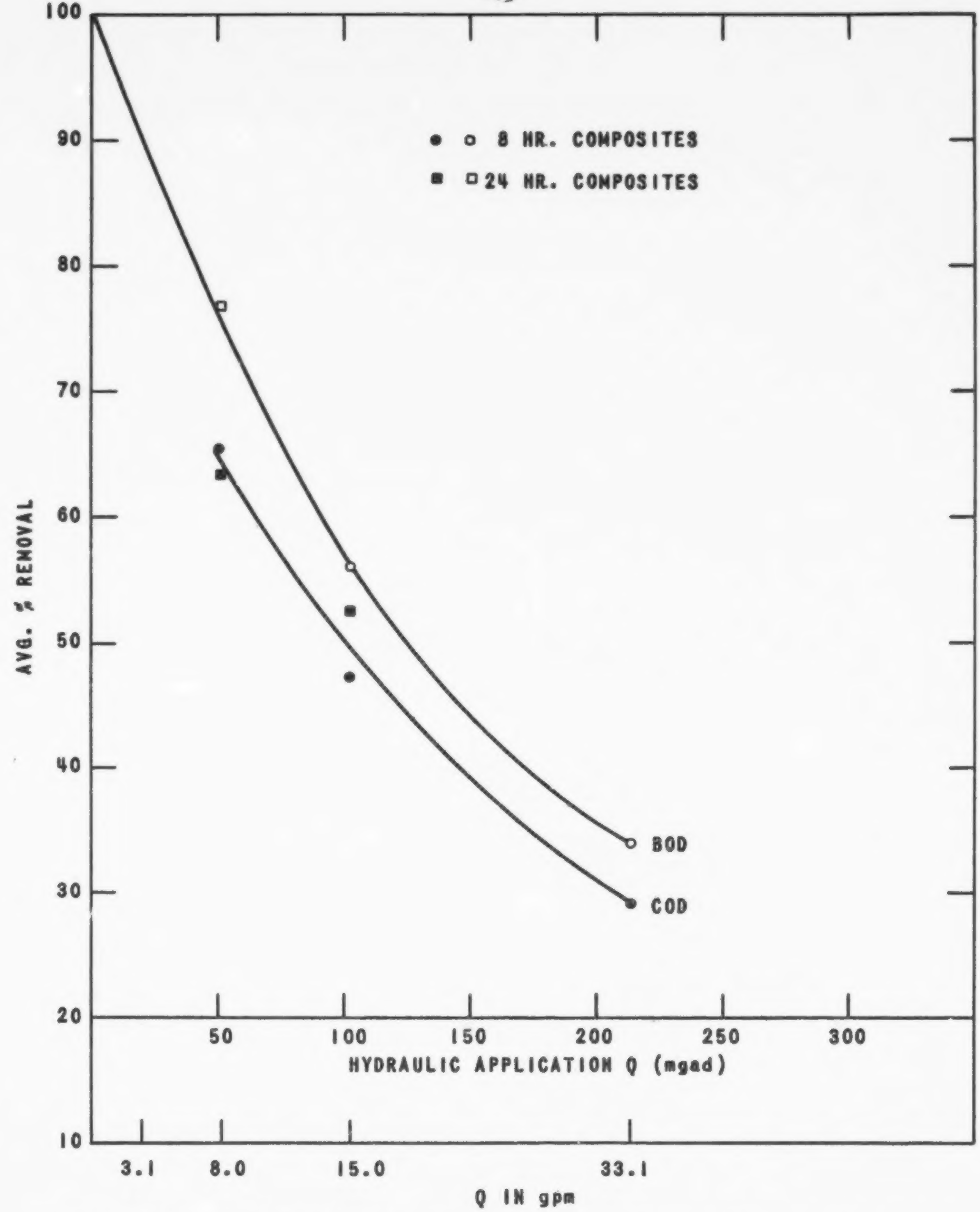
C-15



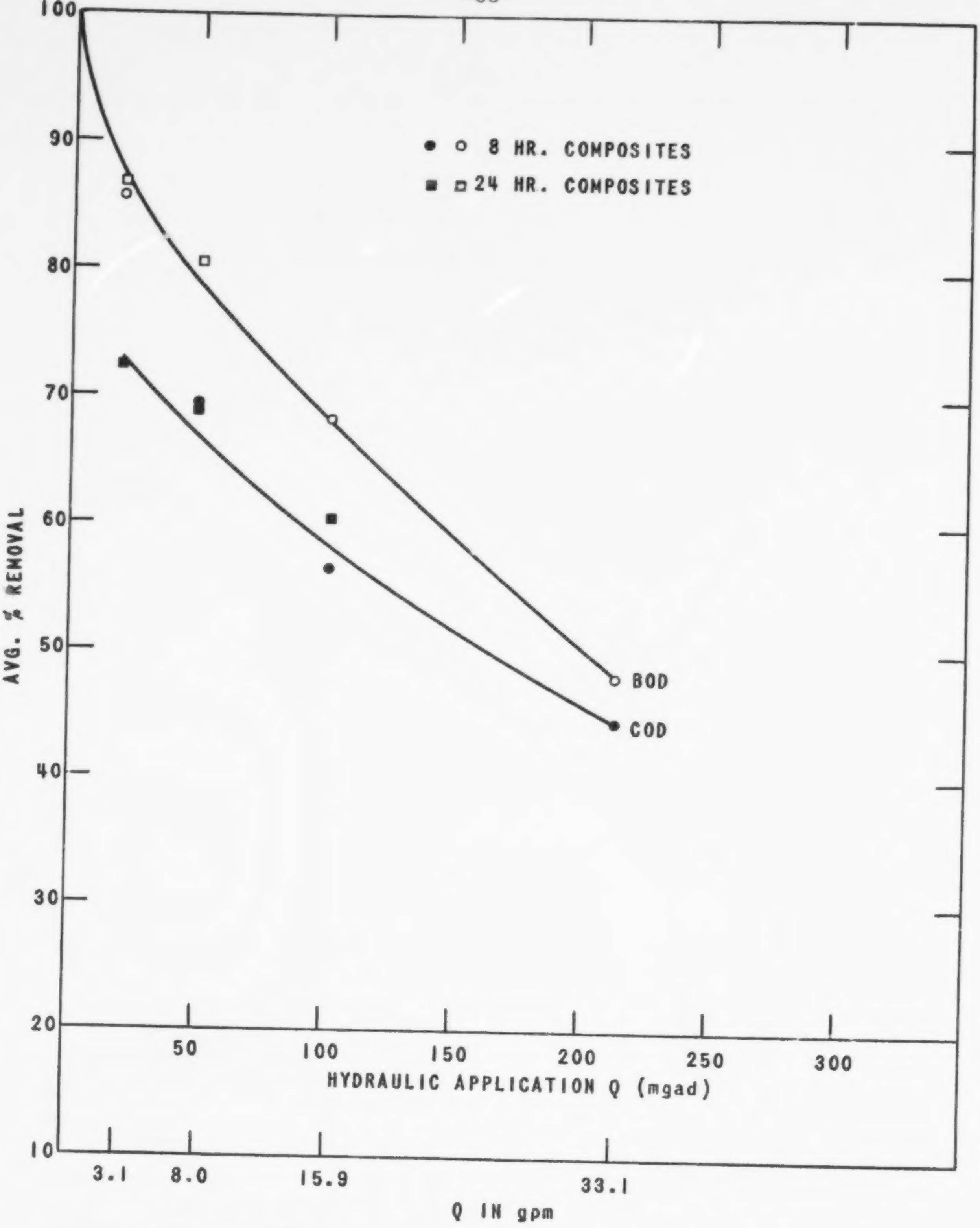
RELATIONSHIP OF % COD REMAINING TO DEPTH FOR AUTOMATICALLY COLLECTED LABORATORY SETTLED SAMPLES BASED ON 42 FOOT DEPTH SAMPLES IF % REMAINING = $100 - 10^{-KD}$



RELATIONSHIP OF % COD REMAINING TO DEPTH FOR AUTOMATICALLY COLLECTED TANK SETTLED SAMPLES BASED ON 42 FOOT DEPTH SAMPLES, IF % REMAINING = $100-10^{-KD}$



RELATIONSHIP OF HYDRAULIC APPLICATION RATE TO MEAN BOD AND COD REMOVAL FOR AUTOMATICALLY COLLECTED, TANK SETTLED SAMPLES AT 42 FOOT DEPTH



RELATIONSHIP OF HYDRAULIC APPLICATION RATE TO MEAN BOD AND COD REMOVAL FOR AUTOMATICALLY COLLECTED, LABORATORY SETTLED SAMPLES AT 42 FOOT DEPTH

C-19

BATTLE CREEK DOWPAC HCS PILOT PLANT
OBSERVED DATA - 33.1 G.P.M. DIRECT APPLICATION RATE

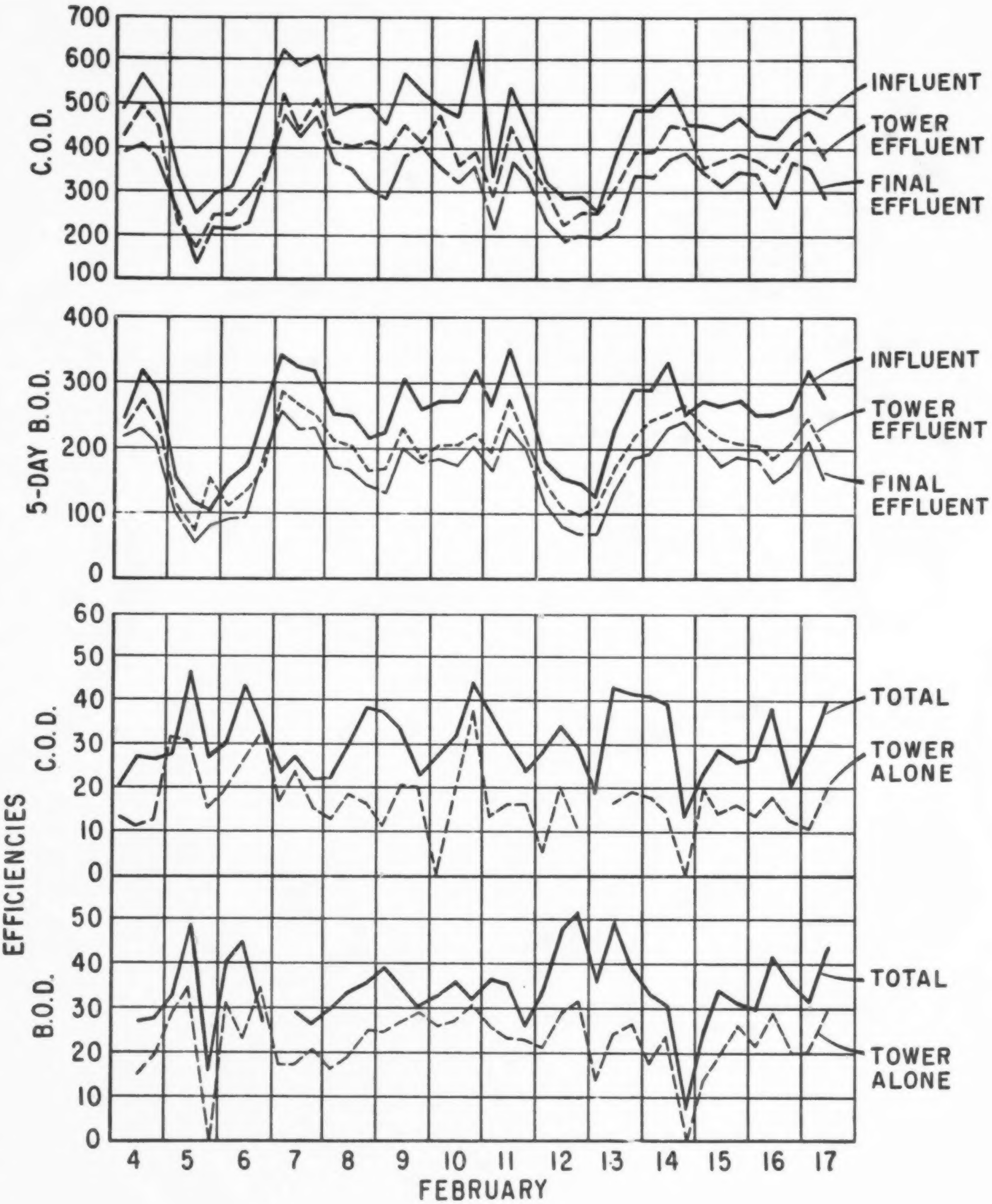


Fig. C-20

BATTLE CREEK DOWPAC HCS PILOT PLANT
OBSERVED DATA - 15.9 G.P.M. DIRECT APPLICATION RATE

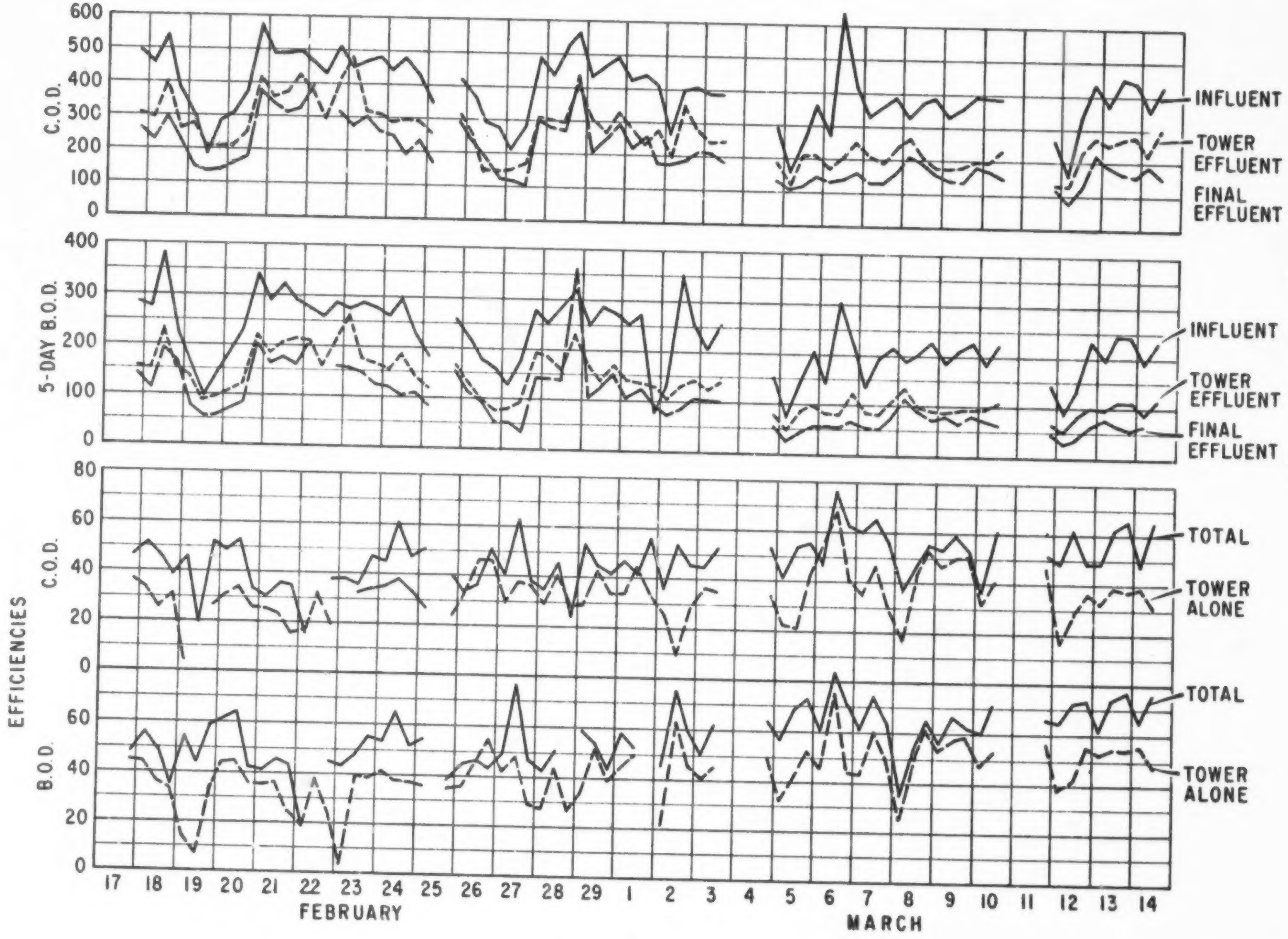


Fig. C-21

BATTLE CREEK DOWPAC HCS PILOT PLANT

OBSERVED DATA - 16.0 G.P.M. DIRECT APPLICATION RATE plus 16.0 G.P.M. RECYCLE OF TOWER EFFLUENT

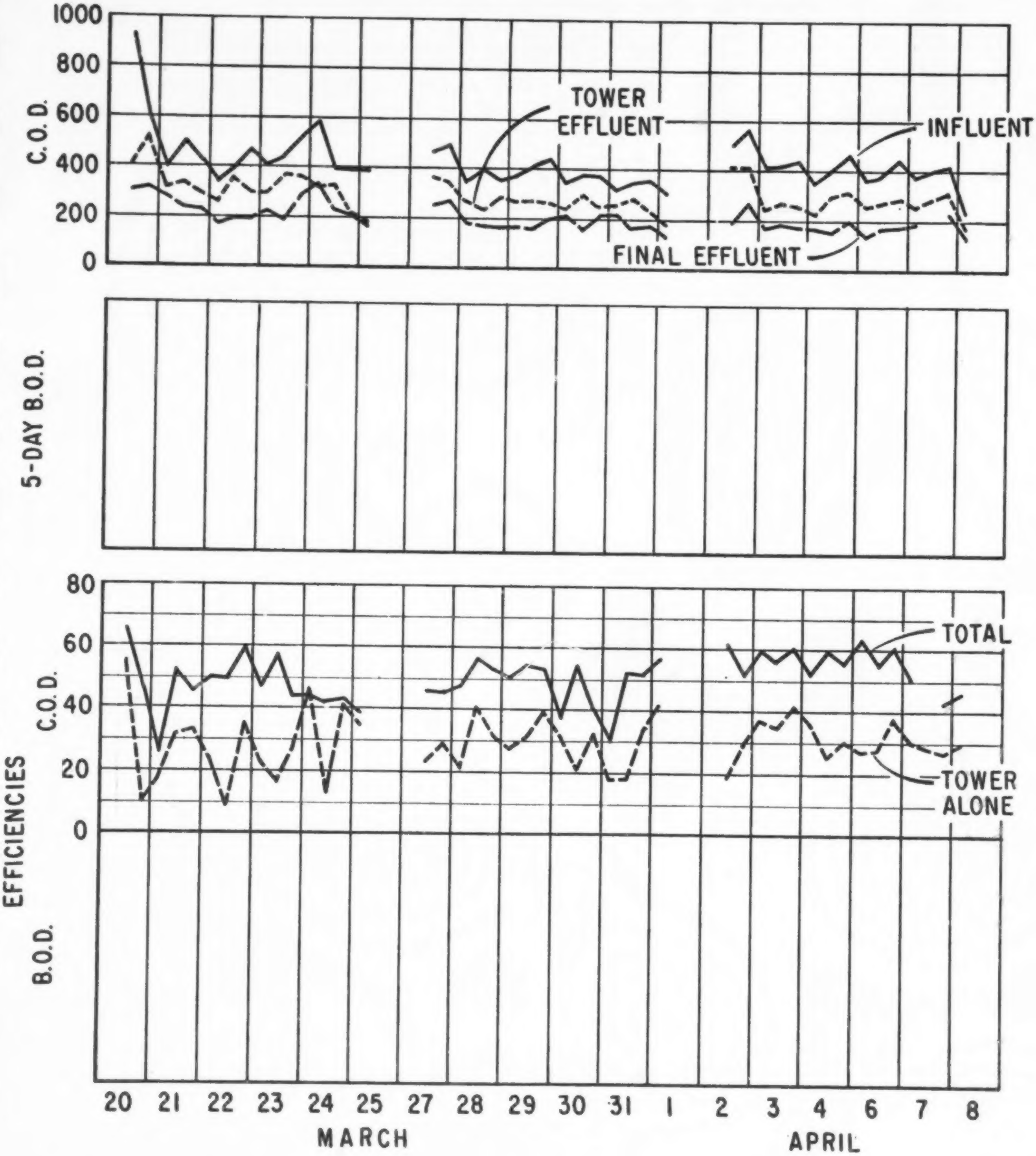


Fig. C-22

BATTLE CREEK DOWPAC HCS PILOT PLANT
OBSERVED DATA - 8.0G.P.M. DIRECT APPLICATION RATE

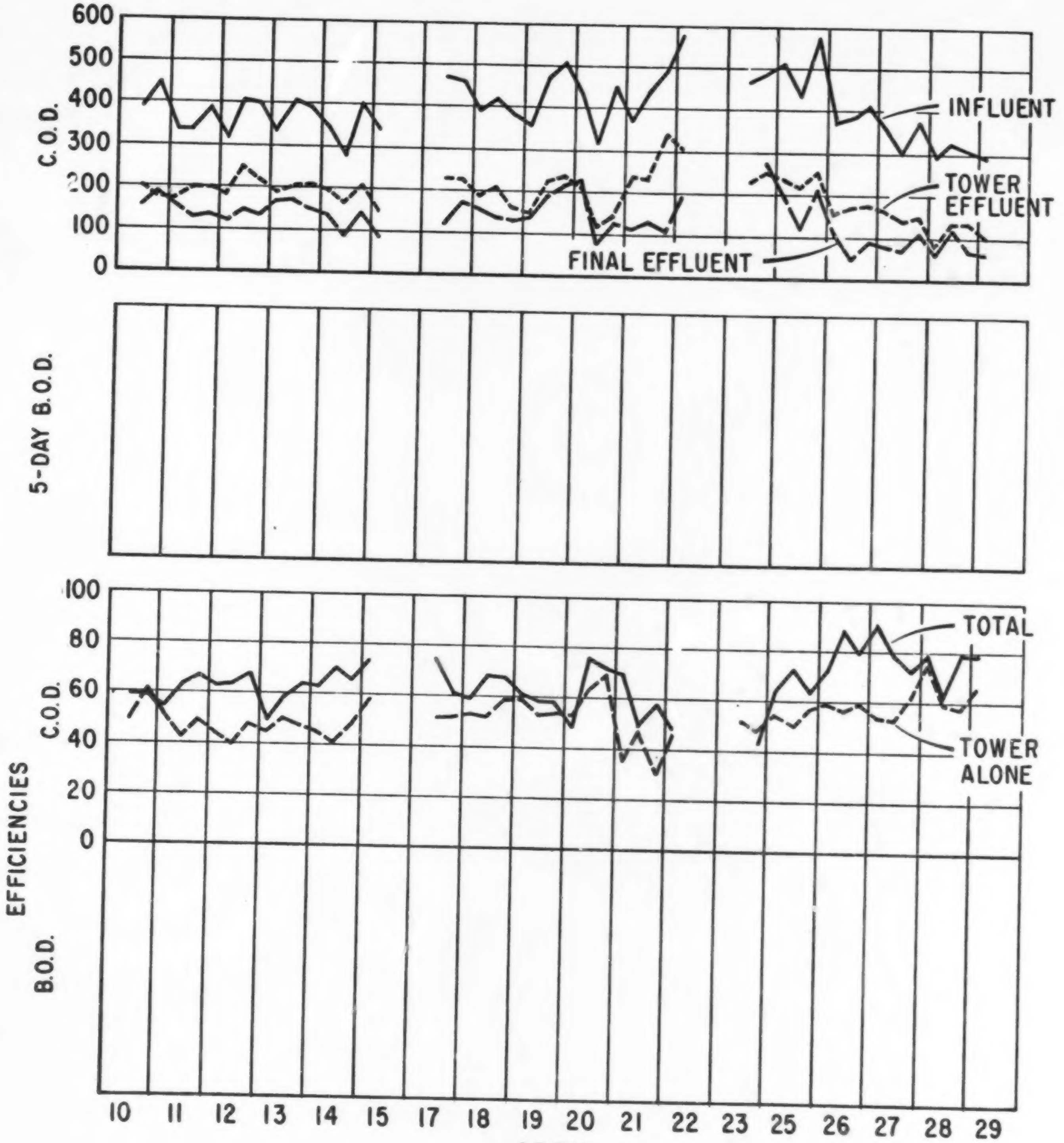


Fig. C-23

BATTLE CREEK DOWPAC HCS PILOT PLANT

OBSERVED DATA - 3.1 G.P.M. DIRECT APPLICATION RATE

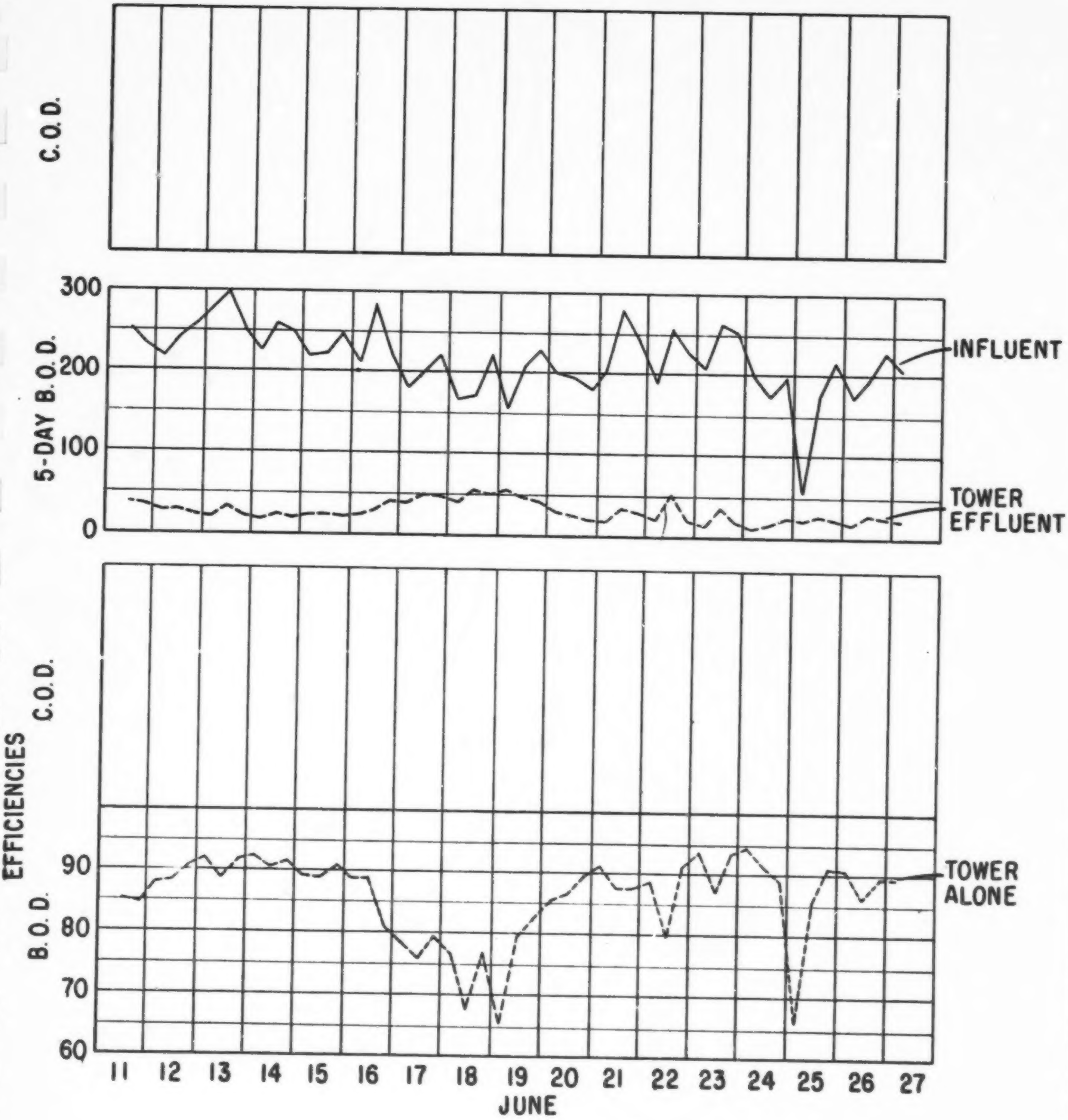


Fig. C-24

APPENDIX

to the

Report of the Battle Creek Pilot Plant Project

Steering Committee:

A STUDY OF THE PERFORMANCE OF DOWPAC HCS WHEN APPLIED TO THE TREATMENT OF SETTLED SEWAGE FROM THE CITY OF BATTLE CREEK, MICHIGAN

January to July, 1956

Data Assembled and Compiled by: A. E. Becher, Jr., United States Public Health Service
E. H. Bryan, The Dow Chemical Company

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Table A-1
CITY OF BATTLE CREEK PILOT PLANT STUDY
Summary of Sampling Schedules

Hydraulic Rate - GPM	Inclusive Sampling Period	Description of Samples Taken During Period	Sampling Point (See Fig. 9)	Collection Time	Analyses Performed* Unsettled	Analyses Performed* Settled**	Remarks
33.1	4 PM February 3 to 4 PM February 10	8-Hour Composites of Samples Taken at 10-minute intervals	D	4 PM, 12 M and 8 AM	BOD, COD	None	
			A		"	"	
			B		"	"	
		Hourly Grab Samples	D	Hourly	COD	None	3 PM January 31 to 4 PM February 10
33.1	4 PM February 10 to 4 PM February 17	8-Hour composites of samples Taken at 10-minute intervals	D	4 PM, 12 M and 8 AM	BOD, COD	None	
			A		"	"	
			B		"	"	
		24-hour composites of samples taken at 10-minute intervals	A	8 AM	None	BOD, COD	
		4-hour composites of samples taken at 30-minute intervals	D	12 N	BOD, COD	None	
			R	"	"	"	
		" "	S	"	"	"	
		" "	T	"	"	"	
		" "	A	"	"	"	
		" "	B	"	"	"	
15.9	4 PM February 17 to 4 PM March 14	8-hour composites of samples taken at 10-minute intervals	D	4 PM, 12 M and 8 AM	BOD, COD	None	
			A		"	"	
			B		"	"	
		24-hour composites of samples taken at 10-minute intervals	D	8 AM	BOD, COD	None	Unsettled Samples from March 1
			A	8 AM	"	BOD, COD	
			B	8 AM	"	None	
		4-hour composites of samples taken at 30-minute intervals	D	12 N	BOD,COD,SS,VSS	None	
			R	"	None	BOD, COD	Discontinued on March 2
		" "	S	"	None	"	
		" "	T	"	None	"	
		" "	A	"	SS, VSS	BOD,COD,SS,VSS	
		" "	B	"	BOD,COD,SS,VSS	None	

* Abbreviations: BOD - Biochemical Oxygen Demand, 5-days at 20°C.
COD - Chemical Oxygen Demand (Dichromate)
SS, VSS - Suspended and Volatile Suspended Solids, resp.

** 8-hour and 24-hour composites settled 1 hour; 4-hour composites settled 30 minutes. (See: sampling and Analytical Procedures)

Table A-1, CITY OF BATTLE CREEK PILOT PLANT STUDY, Summary of Sampling Schedules, Continued

Hydraulic Rate-GPM	Inclusive Sampling Period	Description of Samples Taken During Period	Sampling Point (See Figure. 9)	Collection Time	Analyses Performed Unsettled	Analyses Performed Settled	Remarks
32 GPM (total)w/ 1:1 Recir-culation	8 AM March 20 to 8 AM April 8	8-hour composites of samples	D	4 PM, 12 M	COD	None	Rate changed at 4 PM, March 14
		taken at	A	and	"	"	
		10-minute intervals	B	8 AM	"	"	
		24-hour composites of samples	D	8 AM	COD	None	
		taken at	A	"	"	COD	
		10-minute intervals	B	"	"	None	
		4-hour composites of samples	D	12 N	COD,SS,VSS	None	
		taken at 30-minute intervals	S	"	None	COD	
		" "	A	"	COD,SS,VSS	COD,SS,VSS	
		" "	B	"	COD,SS,VSS	None	
8 GPM	8 AM April 10 to 8 AM April 29	8-hour composites of samples	D	4 PM, 12 M	COD	None	Rate changed at 8 AM, April 8
		taken at	A	and	COD	None	
		10-minute intervals	B	8 AM	COD	None	
		24-hour composites of samples	D	8 AM	COD	None	
		taken at	A	8 AM	COD	COD	
		10-minute intervals	B	8 AM	COD	None	
		4-hour composites of samples	D	12 N	COD,SS,VSS	None	
		taken at 30-minute intervals	S	"	None	COD	
		" "	A	"	COD,SS,VSS	COD,SS,VSS	
		" "	B	"	COD,SS,VSS	None	
3.1 GPM	8 AM June 11 to 8 AM June 27	8-hour composites of samples	D	4 PM, 12 M	BOD	None	Rate changed at 10 AM, June 5
		taken at 10-minute intervals	A	and 8 AM	None	BOD	
		24-hour composites of samples	D	8 AM	BOD, COD	None	
		taken at 10-minute intervals	A	8 AM	BOD, COD	BOD, COD	
		4-hour composites of samples	D	12 N	BOD,SS,VSS	None	
		taken at 30-minute intervals	R	"	None	BOD	
		" "	S	"	None	BOD	
		" "	T	"	None	BOD	
		" "	A	"	BOD,SS,VSS	BOD,SS,VSS	

Table A-2

Pilot Plant Influent* Data

Hourly Variations in Flow and Chemical Oxygen Demand Concentration

Date	Time	Mean Flow (MGD)*	COD (ppm)*	COD (1000#/Day)
Jan. 31	2PM - 3PM	7.2	507	30.5
	3 - 4	7.8	435	28.3
	4 - 5	7.9	445	29.3
	5 - 6	8.0	511	34.1
	6 - 7	8.1	478	32.3
	7 - 8	8.5	468	33.2
	8 - 9	9.3	531	41.2
	9 - 10	9.3	456	35.4
	10 - 11	8.5	429	30.4
	11 - 12M	8.5	399	28.3
Feb. 1	12 - 1AM	8.3	395	27.4
	1 - 2	8.2	384	26.3
	2 - 3	8.2	414	28.3
	3 - 4	8.1	378	25.6
	4 - 5	8.0	357	23.8
	5 - 6	7.5	330	20.7
	6 - 7	5.2	360	15.6
	7 - 8	4.4	345	12.7
	8 - 9	5.0	286	11.9
	9 - 10	6.2	285	14.7
	10 - 11	7.0	352	20.6
	11 - 12N	7.3	292	17.8
	12 - 1PM	7.5	372	23.3
	1 - 2	7.8	384	25.0
Feb. 3	4PM - 5PM	6.9	593	34.1
	5 - 6	7.0	653	38.1
	6 - 7	7.1	629	37.2
	7 - 8	7.2	564	33.9
	8 - 9	7.3	528	32.2
	9 - 10	7.3	560	34.1
	10 - 11	7.2	556	33.4
	11 - 12M	7.0	525	30.6
Feb. 4	12 - 1AM	7.0	495	28.9
	1 - 2	7.0	489	28.6
	2 - 3	6.9	498	28.7
	3 - 4	6.8	496	28.1
	4 - 5	6.7	477	26.6
	5 - 6	6.6	478	26.3
	6 - 7	4.6	538	20.7

*Notes at end of this table

Table A-2, Pilot Plant Influent Data, Cont'd.

Date	Time	Mean Flow (MGD)	COD (ppm)	COD (1000#/Day)
Feb. 4	7AM - 8AM	4.6	496	19.0
	8 - 9	4.6	456	17.4
	9 - 10	5.0	551	22.9
	10 - 11	6.5	601	32.5
	11 - 12N	6.8	623	35.3
	12 - 1PM	6.8	597	33.8
	1 - 2	6.8	604	34.3
	2 - 3	6.5	641	34.7
	3 - 4	6.2	515	25.6
	4 - 5	6.0	503	25.2
	5 - 6	6.0	568	28.4
	6 - 7	6.1	584	29.7
	7 - 8	6.1	538	27.4
	8 - 9	6.1	661	33.6
	9 - 10	6.0	508	25.4
	10 - 11	5.9	462	22.7
	11 - 12M	5.8	408	19.8
Feb. 5	12 - 1AM	5.8	379	18.3
	1 - 2	5.8	493	23.9
	2 - 3	5.8	455	22.0
	3 - 4	5.7	457	21.7
	4 - 5	3.5	320	9.3
	5 - 6	3.5	293	8.6
	6 - 7	3.5	289	8.4
	7 - 8	3.4	385	10.9
	8 - 9	4.5	225	8.5
	9 - 10	4.8	234	9.3
	10 - 11	5.0	225	9.3
	11 - 12N	4.9	230	9.4
	12 - 1PM	5.2	256	11.1
	1 - 2	5.2	228	9.9
	2 - 3	5.3	244	10.7
	3 - 4	5.3	265	11.7
	4 - 5	5.3	303	13.4
	5 - 6	6.6	270	14.8
	6 - 7	7.7	289	18.5
	7 - 8	7.7	343	22.0
	8 - 9	6.9	349	20.1
	9 - 10	4.2	347	12.2
	10 - 11	4.1	327	11.2
	11 - 12M	4.1	321	11.0
Feb. 6	12 - 1AM	4.1	313	10.7
	1 - 2	4.2	299	10.5
	2 - 3	4.2	291	10.2
	3 - 4	5.2	319	13.8
	4 - 5	5.6	331	15.4

Table A-2, Pilot Plant Influent Data, Cont'd.

Date	Time	Mean Flow (MGD)	COD (ppm)	COD (1000#/Day)
Feb. 6	5AM - 6AM	6.0	325	16.3
	6 - 7	6.8	335	19.0
	7 - 8	6.8	293	16.6
	8 - 9	6.7	299	16.7
	9 - 10	6.7	258	14.4
	10 - 11	6.7	318	17.8
	11 - 12N	6.8	365	20.7
	12 - 1PM	7.0	390	22.8
	1 - 2	7.7	423	27.2
	2 - 3	11.3	505	47.5
	3 - 4	12.1	654	66.0
	4 - 5	11.8	612	60.2
	5 - 6	11.5	548	52.6
	6 - 7	11.2	544	46.3
	7 - 8	7.6	539	34.2
	8 - 9	6.9	542	31.2
	9 - 10	6.8	489	27.8
	10 - 11	6.8	469	26.6
	11 - 12M	6.7	471	26.3
Feb. 7	12 - 1AM	6.1	605	30.8
	1 - 2	6.5	725	39.4
	2 - 3	6.7	676	37.9
	3 - 4	6.7	689	38.5
	4 - 5	6.7	654	36.6
	5 - 6	6.8	597	33.9
	6 - 7	6.7	550	30.8
	7 - 8	6.7	548	30.8
	8 - 9	6.8	579	32.9
	9 - 10	7.2	584	35.1
	10 - 11	7.0	600	35.0
	11 - 12N	7.2	565	33.9
	12 - 1PM	7.5	535	33.5
	1 - 2	7.7	519	33.4
	2 - 3	7.8	665	43.2
	3 - 4	8.0	743	49.5
	4 - 5	8.1	707	47.7
	5 - 6	8.2	690	47.2
	6 - 7	8.2	770	52.7
	7 - 8	8.2	624	43.5
	8 - 9	8.2	594	40.7
	9 - 10	8.2	558	38.2
	10 - 11	8.1	489	33.0
	11 - 12M	8.0	490	32.7

Table A-2, Pilot Plant Influent Data, Cont'd.

Date	Time	Mean Flow (MGD)	COD (ppm)	COD (1000#/Day)
Feb. 8	12M - 1AM	8.0	484	32.3
	1 - 2	7.8	500	32.5
	2 - 3	7.7	500	32.1
	3 - 4	7.5	495	30.9
	4 - 5	7.3	475	28.9
	5 - 6	7.1	474	28.1
	6 - 7	6.4	480	25.6
	7 - 8	5.3	485	21.4
	8 - 9	6.9	437	25.1
	9 - 10	6.3	440	23.1
	10 - 11	7.1	460	27.2
	11 - 12N	7.5	585	36.5
	12 - 1PM	7.9	502	33.0
	1 - 2	8.1	480	32.4
	2 - 3	8.3	485	33.5
	3 - 4	8.5	562	39.1
	4 - 5	8.8	526	38.5
	5 - 6	12.3	495	50.8
	6 - 7	12.5	515	53.6
	7 - 8	12.1	532	53.6
	8 - 9	11.7	490	47.8
	9 - 10	11.2	462	43.2
	10 - 11	9.1	428	32.5
	11 - 12M	7.0	415	24.2
Feb. 9	12 - 1AM	5.7	479	22.8
	1 - 2	5.7	460	21.9
	2 - 3	5.7	468	22.3
	3 - 4	5.7	451	21.4
	4 - 5	5.7	410	19.5
	5 - 6	5.7	481	22.8
	6 - 7	5.6	441	20.6
	7 - 8	5.5	414	19.0
	8 - 9	5.7	440	20.9
	9 - 10	6.1	686	34.9
	10 - 11	6.9	655	39.5
	11 - 12N	8.0	695	46.3
	12 - 1PM	8.2	631	43.2
	1 - 2	8.4	557	38.9
	2 - 3	8.8	554	39.9
	3 - 4	9.2	519	39.9
	4 - 5	12.2	538	54.7
	5 - 6	11.8	553	54.5
	6 - 7	11.5	505	48.4
	7 - 8	11.0	526	48.3
	8 - 9	10.8	552	49.7
	9 - 10	10.2	502	42.7
	10 - 11	10.0	465	38.8
	11 - 12M	9.6	465	37.3

Table A-2, Pilot Plant Influent Data, Cont'd.

Date	Time	Mean Flow (MGD)	COD (ppm)	COD (1000#/Day)
Feb. 10	12M - 1AM	5.8	565	27.3
	1 - 2	5.8	537	25.9
	2 - 3	5.8	544	26.3
	3 - 4	5.8	570	27.6
	4 - 5	5.8	477	23.1
	5 - 6	5.7	421	20.0
	6 - 7	5.4	400	18.0
	7 - 8	4.8	439	17.6
	8 - 9	6.4	443	23.7
	9 - 10	7.0	404	23.6
	10 - 11	7.3	476	28.9
	11 - 12N	7.5	570	35.6
	12 - 1PM	7.7	539	34.6
	1 - 2	8.0	481	32.0
	2 - 3	8.2	449	30.8
	3 - 4	8.3	551	38.1
MEAN - February 3 - 10, 1956		7.05	486	29.3

*Battle Creek Sewage Treatment Plant Effluent
Flow data from continuous recorder in main plant

Chemical analysis on one hour composites made up of samples collected automatically every 10 minutes.

Table A-3

Dowpac HCS Pilot Plant, Battle Creek, Michigan

Observed Summary Data

Hydraulic Rate - 33.1 GPM

Date	Sample	Determin- ation	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Reduction-Percent in Tower	Reduction-Percent Total
Feb 3 1956	4p-12M	BOD	184	255	187	--	--
		COD	540	470	539	13.0	0.2
		Ratio*	---	0.542	---	--	--
Feb 4	12M-8a	BOD	245	229	220	--	--
		COD	496**	428	396	13.7	20.2
		Ratio	---	0.533	0.553	--	--
	8a-4p	BOD	320	273	234	14.7	26.9
		COD	565	499	408	11.7	27.8
		Ratio	0.553	0.543	0.570	--	--
	4p-12M	BOD	288	233	209	19.1	27.4
		COD	507	444	375	12.4	26.0
		Ratio	0.564	0.524	0.553	--	--
Feb 5	12M-8a	BOD	157	112	105	28.7	33.1
		COD	334	230	241	31.1	27.9
		Ratio	0.467	0.380	0.339	31.1	--
	8a-4p	BOD	117	76.4	59.4	34.7	49.2
		COD	246	169	131	31.0	46.5
		Ratio	0.477	0.423	0.454	--	--
	4p-12M	BOD	103	159	87.4	0	15.2
		COD	296	249	218	15.9	26.4
		Ratio	0.348	0.638	0.403	--	--
Feb 6	12M-8a	BOD	156	108	94.6	30.8	39.4
		COD	303	243	212	19.8	30.0
		Ratio	0.515	0.444	0.447	--	--
	8a-4p	BOD	178	138	97.6	22.5	45.2
		COD	398	294	225	26.1	43.5
		Ratio	0.346	0.469	0.433	--	--
	4p-12M	BOD	260	171	190	34.2	26.9
		COD	535	359	354	32.9	33.8
		Ratio	0.487	0.477	0.533	--	--

* Ratio = $\frac{BOD}{COD}$

**Calculated from hourly samples

Table A-3, Observed Summary Data at 33.1 GPM, Cont'd.

Date	Sample	Determination	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Reduction-Percent in Tower	Reduction-Percent Total
Feb 7 1956	12M-8a	BOD	344	286	256	16.9	--
		COD	625	521	477	16.6	23.7
		Ratio	0.545	0.546	0.537	--	--
	8a-4p	BOD	322	268	230	16.8	28.6
		COD	590	439	426	25.6	27.8
		Ratio	0.546	0.610	0.541	--	--
	4p-12M	BOD	318	252	235	20.8	26.1
		COD	608	513	472	15.6	22.4
		Ratio	0.534	0.492	0.498	--	--
Feb 8	12m-8a	BOD	251	211	175	16.0	30.3
		COD	473	413	366	12.7	22.6
		Ratio	0.531	0.509	0.478	--	--
	8a-4p	BOD	250	203	166	18.8	33.6
		COD	494	401	348	18.8	29.6
		Ratio	0.508	0.509	0.487	--	--
	4P-12M	BOD	219	165	141	24.7	35.6
		COD	497	413	304	16.9	38.8
		Ratio	0.443	0.427	0.467	--	--
Feb 9	12M-8a	BOD	225	170	137	24.5	39.1
		COD	453	400	284	11.7	37.3
		Ratio	0.500	0.427	0.474	--	--
	8a-4p	BOD	309	228	200	26.2	35.3
		COD	570	448	382	21.4	33.0
		Ratio	0.553	0.507	0.524	--	--
	4p-12M	BOD	261	185	181	29.1	30.7
		COD	520	410	404	21.2	22.3
		Ratio	0.502	0.452	0.447	--	--
Feb 10	12M-8a	BOD	271	202	184	25.5	32.1
		COD	491	481	359	2.0	26.9
		Ratio	0.564	0.419	0.512	--	--
	8a-4p	BOD	274	202	178	26.3	35.0
		COD	464	367	316	20.9	31.9
		Ratio	0.597	0.547	0.561	--	--
	4p-12M	BOD	319	220	217	31.0	32.0
		COD	641	398	359	37.9	44.0
		Ratio	0.497	0.552	0.603	--	--

Table A-3, Observed Summary Data at 33.1 GPM, Cont'd.

Date	Sample	Determination	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Reduction-Percent	
						in Tower	Total
Feb 11	12M-8a	BOD	263	195	168	25.9	36.1
		COD	331	285	211	13.9	36.3
		Ratio	0.795	0.684	0.797	--	--
	8a-4p	BOD	359	278	233	22.6	35.1
		COD	539	451	369	16.3	31.5
		Ratio	0.698	0.617	0.630	--	--
	4p-12M	BOD	271	211	201	22.2	25.8
		COD	441	369	335	16.3	24.0
		Ratio	0.616	0.570	0.598	--	--
Feb 12	12M-8a	BOD	180	143	119	20.6	33.9
		COD	323	307	231	5.0	28.5
		Ratio	0.556	0.464	0.515	--	--
	8a-4p	BOD	152	109	81.2	28.3	46.6
		COD	283	225	186	20.5	34.3
		Ratio	0.536	0.429	0.407	--	--
	4p-12M	BOD	145	99	69.7	31.7	51.9
		COD	282	250	200	11.4	29.1
		Ratio	0.512	0.436	0.349	--	--
Feb 13	12M-8a	BOD	122	107	79.5	12.3	34.8
		COD	246	250	199	--	19.1
		Ratio	0.494	0.428	0.399	--	--
	8a-4p	BOD	227	174	114	23.4	49.8
		COD	380	314	217	17.4	42.9
		Ratio	0.578	0.554	0.528	--	--
	4p-12M	BOD	296	219	183	26.0	38.2
		COD	486	390	331	19.8	31.9
		Ratio	0.611	0.563	0.548	--	--
Feb 14	12M-8a	BOD	291	242	197	16.8	32.3
		COD	483	395	335	18.2	30.7
		Ratio	0.604	0.613	0.588	--	--
	8a-4p	BOD	337	257	236	23.7	30.0
		COD	531	454	374	14.5	29.6
		Ratio	0.636	0.569	0.631	--	--
	4p-12M	BOD	257	261	241	0	6.2
		COD	451	449	392	0.5	13.1
		Ratio	0.572	0.582	0.619	--	--

Table A-3, Observed Summary Data at 33.1 GPM, Cont'd.

Date	Sample	Determination	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Reduction-Percent	
						in Tower	Total
Feb 15	12M-8a	BOD	271	238	205	12.2	24.4
		COD	445	355	346	20.2	22.3
		Ratio	0.612	0.671	0.593	--	--
	8a-4p	BOD	267	215	177	19.5	33.7
		COD	442	376	313	14.9	29.2
		Ratio	0.605	0.570	0.566	--	--
	4p-12M	BOD	275	206	190	25.1	30.9
		COD	462	387	341	16.2	26.2
		Ratio	0.594	0.533	0.557	--	--
Feb 16	12M-8a	BOD	259	205	182	20.9	29.7
		COD	438	377	321	13.9	26.7
		Ratio	0.591	0.543	0.567	--	--
	8a-4p	BOD	256	184	152	28.1	40.6
		COD	421	343	260	18.5	38.3
		Ratio	0.609	0.537	0.584	--	--
	4p-12M	BOD	260	210	170	19.2	34.6
		COD	462	406	368	12.1	20.4
		Ratio	0.570	0.518	0.462	--	--
Feb 17	12M-8a	BOD	308	247	213	19.8	30.9
		COD	488	435	347	10.9	28.9
		Ratio	0.633	0.568	0.617	--	--
	8a-4p	BOD	280	200	158	28.6	43.6
		COD	469	372	284	20.7	39.5
		Ratio	0.597	0.538	0.557	--	--

Table A-4

Dowpac HCS Pilot Plant, Battle Creek, Michigan

Observed Summary Data

Hydraulic Rate - 15.9 GPM

Date	Sample	Determination	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Removal-Percent	
						in Tower	Total
Feb 17 1956	4p-12M	BOD	280	153	144	45.4	48.6
		COD	493	306	262	37.9	46.9
		Ratio	0.568	0.500	0.550	--	--
Feb 18	12M-8a	BOD	272	150	118	44.9	56.6
		COD	455	299	223	34.3	51.0
		Ratio	0.598	0.502	0.529	--	--
	8a-4p	BOD	378	239	191	36.8	49.5
		COD	540	402	291	25.6	46.1
		Ratio	0.700	0.595	0.656	--	--
	4p-12M	BOD	233	153	152	34.3	34.8
		COD	373	258	227	30.8	39.2
		Ratio	0.625	0.593	0.670	--	--
Feb 19	12M-8a	BOD	159	138	72	13.2	54.7
		COD	294	283	159	3.8	45.9
		Ratio	0.541	0.488	0.453	--	--
	8a-4p	BOD	97	90	54	7.2	44.3
		COD	188	202	132	--	29.8
		Ratio	0.516	0.446	0.409	--	--
	4p-12M	BOD	142	96	58	32.4	59.2
		COD	280	203	133	27.5	52.5
		Ratio	0.507	0.473	0.436	--	--
Feb 20	12M-8a	BOD	183	103	70	43.7	61.8
		COD	302	209	154	30.8	49.0
		Ratio	0.606	0.493	0.455	--	--
	8a-4p	BOD	223	124	79	44.4	64.6
		COD	376	250	176	33.5	53.2
		Ratio	0.593	0.496	0.449	--	--
	4p-12M	BOD	347	220	202	36.6	41.8
		COD	575	418	385	27.3	33.1
		Ratio	0.603	0.526	0.525	--	--

Table A-4, Observed Summary Data at 15.9 GPM, Cont'd.

Date	Sample	Determination	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Removal-Percent	
						in Tower	Total
Feb 21	12M-8a	BOD	282	180	167	36.2	40.8
		COD	487	357	339	26.7	30.4
		Ratio	0.579	0.504	0.493	--	--
	8a-4p	BOD	323	205	174	36.5	46.1
		COD	485	371	309	23.5	36.3
		Ratio	0.666	0.553	0.563	--	--
	4p-12M	BOD	288	218	161	24.3	44.1
		COD	497	422	321	15.1	35.4
		Ratio	0.579	0.517	0.502	--	--
Feb 22	12M-8a	BOD	269	217	214	19.3	20.5
		COD	461	384	386	16.7	16.3
		Ratio	0.584	0.565	0.554	--	--
	8a-4p	BOD	253	157	---	38.0	--
		COD	426	292	---	31.5	--
		Ratio	0.594	0.538	---	--	--
	4p-12M	BOD	284	215	156	24.3	45.1
		COD	509	410	315	19.5	38.1
		Ratio	0.558	0.524	0.495	--	--
Feb 23	12M-8a	BOD	272	262	153	3.7	43.8
		COD	443	477	271	--	38.8
		Ratio	0.614	0.549	0.565	--	--
	8a-4p	BOD	288	173	149	39.9	48.3
		COD	468	312	300	33.3	35.9
		Ratio	0.615	0.554	0.497	--	--
	4p-12M	BOD	277	167	124	39.7	55.2
		COD	478	309	251	35.4	47.5
		Ratio	0.579	0.504	0.494	--	--
Feb 24	12M-8a	BOD	260	152	122	41.5	53.1
		COD	447	283	244	36.7	45.4
		Ratio	0.582	0.537	0.500	--	--
	8a-4p	BOD	296	181	100	38.9	66.2
		COD	481	296	190	38.5	60.5
		Ratio	0.615	0.611	0.526	--	--
	4p-12M	BOD	227	141	111	37.9	51.1
		COD	435	289	230	33.6	47.1
		Ratio	0.522	0.488	0.483	--	--

Table A-4, Observed Summary Data at 15.9 GPM, Cont'd.

Date	Sample	Determination	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Removal-Percent	
						in Tower	Total
Feb 25 1956	12M-8a	BOD	188	120	85	36.2	54.8
		COD	349	252	173	27.8	50.4
		Ratio	0.539	0.476	0.491	--	--
	8a-4p	BOD	---	---	---	--	--
		COD	---	---	---	--	--
		Ratio	---	---	---	--	--
	4p-12M	BOD	254	161	153	36.6	39.8
		COD	415	315	297	24.1	28.4
		Ratio	0.612	0.511	0.515	--	--
Feb 26	12M-8a	BOD	220	137	122	37.7	44.6
		COD	369	250	245	32.3	33.6
		Ratio	0.596	0.548	0.498	--	--
	8a-4p	BOD	176	94	94	46.6	46.6
		COD	290	154	183	46.9	36.9
		Ratio	0.607	0.610	0.514	--	--
	4p-12M	BOD	156	70	57	55.1	63.5
		COD	275	146	135	46.9	50.9
		Ratio	0.567	0.479	0.422	--	--
Feb 27	12M-8a	BOD	126	72	51	42.9	59.5
		COD	211	148	126	29.9	40.3
		Ratio	0.597	0.486	0.405	--	--
	8a-4p	BOD	176	90	38	48.9	78.4
		COD	286	176	108	38.5	62.2
		Ratio	0.615	0.511	0.352	--	--
	4p-12M	BOD	278	197	148	29.1	46.8
		COD	495	311	304	37.2	38.6
		Ratio	0.562	0.633	0.487	--	--
Feb 28	12M-8a	BOD	252	181	144	28.2	42.9
		COD	435	305	282	29.9	35.2
		Ratio	0.579	0.593	0.511	--	--
	8a-4p	BOD	288	159	141	44.8	51.1
		COD	510	298	277	41.6	45.7
		Ratio	0.565	0.534	0.509	--	--
	4p-12M	BOD	321	234	362	27.1	--
		COD	567	418	431	26.3	24.0
		Ratio	0.566	0.560	0.840	--	--

Table A-4, Observed Summary Data at 15.9 GPM, Cont'd.

Date	Sample	Determination	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Removal-Percent in Tower	Removal-Percent Total
Feb 29 1956	12M-8a	BOD	250	163	102	34.8	59.2
		COD	429	303	201	29.4	53.2
		Ratio	0.583	0.538	0.507	--	--
	8a-4p	BOD	287	137	133	52.3	53.7
		COD	459	259	253	43.6	44.9
		Ratio	0.625	0.529	0.526	--	--
	4p-12M	BOD	274	166	153	39.4	44.2
		COD	494	329	291	33.4	41.1
		Ratio	0.555	0.505	0.526	--	--
Mar 1	12M-8a	BOD	256	140	107	45.3	58.2
		COD	421	280	220	33.5	47.8
		Ratio	0.608	0.500	0.486	--	--
	8a-4p	BOD	270	135	126	50.0	53.3
		COD	435	244	254	43.9	41.6
		Ratio	0.621	0.553	0.496	--	--
	4p-12M	BOD	74	126	75	--	--
		COD	403	273	179	32.3	55.6
		Ratio	0.184	0.462	0.419	--	--
Mar 2	12M-8a	BOD	130	103	69	20.8	46.9
		COD	267	199	171	25.5	36.0
		Ratio	0.487	0.518	0.404	--	--
	8a-4p	BOD	352	130	86	63.1	75.6
		COD	394	355	183	9.9	53.6
		Ratio	0.893	0.366	0.470	--	--
	4p-12M	BOD	258	142	105	45.0	59.3
		COD	401	284	218	29.2	45.6
		Ratio	0.643	0.500	0.482	--	--
Mar 3	12M-8a	BOD	202	121	101	40.1	50.0
		COD	384	242	213	37.0	44.5
		Ratio	0.526	0.500	0.474	--	--
	8a-4p	BOD	254	138	100	45.7	60.6
		COD	385	247	188	35.9	51.2
		Ratio	0.660	0.559	0.532	--	--
Mar 4	4p-12M	BOD	150	75	55	50.0	63.3
		COD	291	190	140	34.7	51.9
		Ratio	0.515	0.395	0.393	--	--

Table A-4, Observed Summary Data at 15.9 GPM, Cont'd.

Date	Sample	Determin-Ation	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Removal-Percent	
						in Tower	Total
Mar 5 1956	12M-8a	BOD	71	48	30	32.4	57.8
		COD	169	133	117	21.3	30.8
		Ratio	0.420	0.361	0.256	--	--
	8a-4p	BOD	139	81	43	41.7	69.1
		COD	266	212	123	20.3	53.8
		Ratio	0.523	0.382	0.350	--	--
	4p-12M	BOD	204	97	55	52.5	73.0
		COD	371	214	166	42.3	55.3
		Ratio	0.550	0.453	0.331	--	--
Mar 6	12M-8a	BOD	143	77	57	46.2	60.1
		COD	271	177	145	34.7	46.5
		Ratio	0.528	0.435	0.393	--	--
	8a-4p	BOD	304	76	53	75.0	82.6
		COD	633	201	145	68.3	77.1
		Ratio	0.480	0.378	0.366	--	--
	4p-12M	BOD	225	125	66	44.5	70.7
		COD	426	255	160	40.2	62.5
		Ratio	0.528	0.490	0.413	--	--
Mar 7	12M-8a	BOD	137	79	53	42.3	61.3
		COD	325	212	130	34.8	60.0
		Ratio	0.422	0.373	0.408	--	--
	8a-4p	BOD	193	76	51	60.6	73.6
		COD	357	189	124	47.1	65.3
		Ratio	0.541	0.402	0.411	--	--
	4p-12M	BOD	212	108	76	49.1	64.2
		COD	385	231	169	40.0	56.1
		Ratio	0.551	0.468	0.450	--	--
Mar 8	12M-8a	BOD	183	137	118	25.1	35.5
		COD	325	267	207	17.9	36.3
		Ratio	0.563	0.513	0.570	--	--
	8a-4p	BOD	201	96	95	52.2	52.7
		COD	364	209	193	42.6	47.0
		Ratio	0.552	0.459	0.492	--	--
	4p-12M	BOD	226	87	76	61.5	66.4
		COD	382	176	168	53.9	56.0
		Ratio	0.592	0.494	0.452	--	--

Table A-4, Observed Summary Data at 15.9 GPM, Cont'd.

Date	Sample	Determination	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Removal-Percent in Tower	Removal-Percent Total
Mar 9 1956	12M-8a	BOD	182	83	78	54.4	57.2
		COD	327	173	148	47.1	54.8
		Ratio	0.557	0.480	0.527	--	--
	8a-4p	BOD	207	87	67	58.0	67.6
		COD	355	178	144	49.9	59.4
		Ratio	0.583	0.489	0.465	--	--
	4p-12M	BOD	223	90	83	59.7	62.8
		COD	385	192	183	50.1	52.5
		Ratio	0.579	0.469	0.454	--	--
Mar 10	12M-8a	BOD	183	95	73	48.1	60.1
		COD	284	192	177	32.4	37.7
		Ratio	0.644	0.495	0.412	--	--
	8a-4p	BOD	222	103	63	53.6	71.6
		COD	382	229	151	40.1	60.5
		Ratio	0.581	0.450	0.417	--	--
Mar 11	4p-12M						
	12M-8a	No samples taken					
	8a-4p						
Mar 12	4p-12M	BOD	143	61	48	57.4	66.4
		COD	262	138	128	47.3	51.2
		Ratio	0.546	0.442	0.375	--	--
	12M-8a	BOD	81	50	28	38.3	65.4
		COD	157	131	80	16.6	49.1
		Ratio	0.516	0.382	0.350	--	--
	8a-4p	BOD	134	79	38	41.1	71.7
		COD	327	234	124	28.5	62.1
		Ratio	0.410	0.338	0.306	--	--
	4p-12M	BOD	229	99	62	56.8	72.9
		COD	431	273	220	36.7	49.0
		Ratio	0.531	0.363	0.282	--	--
Mar 13	12M-8a	BOD	197	94	77	52.3	60.9
		COD	367	250	187	31.9	49.1
		Ratio	0.537	0.376	0.412	--	--
	8a-4p	BOD	247	112	65	54.7	73.7
		COD	427	264	162	38.2	62.1
		Ratio	0.578	0.424	0.401	--	--

Table A-4, Observed Summary Data at 15.9 GMP, Cont'd.

Date	Sample	Determination	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Removal-Percent	
						in Tower	Total
Mar 13	4p-12M	BOD	244	112	55	54.1	77.5
		COD	433	272	148	37.2	65.8
		Ratio	0.564	0.412	0.372	--	--
Mar 14	12M-8a	BOD	183	82	65	55.2	64.5
		COD	357	220	185	38.4	48.2
		Ratio	0.513	0.373	0.351	--	--
	8a-4p	BOD	232	120	57	48.3	75.4
		COD	429	298	150	30.5	65.0
		Ratio	0.541	0.403	0.380	--	--

Table A-5

Dowpac HCS Pilot Plant, Battle Creek, Michigan

Observed Summary Data

Hydraulic Rate - 16 GPM Direct Plus 16 GPM Recirculation

Date	Sample	Influent ppm, COD	Tower Effluent ppm, COD	Final Effluent ppm, COD	Removal-Percent	
					in Tower	Total
Mar 20	8a-4p	916	410	316	55.3	65.5
1956	4p-12M	591	532	320	10.0	45.9
	12M-8a	395	326	292	17.5	26.1
Mar 21	8a-4p	505	345	242	31.7	52.1
	4p-12M	438	293	236	33.1	46.1
Mar 22	12M-8a	345	263	173	23.8	49.9
	8a-4p	391	359	199	8.19	49.1
	4p-12M	479	307	192	35.9	59.9
Mar 23	12M-8a	405	309	211	23.7	47.9
	8a-4p	442	369	188	16.5	57.5
	4p-12M	511	367	284	28.2	44.4
Mar 24	12M-8a	588	321	325	45.4	44.7
	8a-4p	397	342	230	13.9	42.1
	4p-12M	390	228	225	41.5	42.3
Mar 25	12M-8a	289	186	177	35.7	38.8
Mar 27	8a-4p	470	358	256	23.8	45.5
	4p-12M	493	350	271	29.0	45.0
Mar 28	12M-8a	348	277	184	20.4	47.1
	8a-4p	391	233	171	40.4	56.3
	4p-12M	355	241	166	32.1	53.2
Mar 29	12M-8a	369	267	184	27.7	50.1
	8a-4p	406	279	184	31.3	54.7
	4p-12M	442	267	205	39.6	53.6
Mar 30	12M-8a	357	248	224	30.5	37.3
	8a-4p	377	298	169	21.0	55.2
	4p-12M	379	257	227	32.2	40.1
Mar 31	12M-8a	319	260	225	18.5	29.5
	8a-4p	344	279	165	18.9	52.0
	4p-12M	345	228	167	33.9	51.6
Apr 1	12M-8a	301	175	129	41.9	57.2

Table A-5, Observed Summary Data at 16 GPM Direct Plus 16 GPM Recirculation, Cont'd.

					Removal-Percent	
Date	Sample	Influent ppm, COD	Tower Effluent ppm, COD	Final Effluent ppm, COD	in Tower	Total
Apr 3	8a-4p	504	405	194	19.7	61.5
1956	4p-12M	568	405	274	28.7	51.8
Apr 4	12M-8a	406	257	166	36.7	59.1
	8a-4p	410	268	181	34.6	55.9
	4p-12M	438	258	175	41.1	60.1
Apr 5	12M-8a	345	221	169	36.0	51.0
	8a-4p	396	294	162	25.8	59.1
	4p-12M	445	310	199	30.3	55.3
Apr 6	12M-8a	362	263	136	27.4	62.4
	8a-4p	375	269	168	28.3	55.2
	4p-12M	441	273	174	38.1	60.6
Apr 7	12M-8a	372	259	188	30.4	49.5
	8a-4p	393	282	---	28.3	--
	4p-12M	412	304	237	26.2	42.5
Apr 8	12M-8a	237	169	129	28.7	45.6

Table A-6

Dowpac HCS Pilot Plant, Battle Creek, Michigan

Observed Summary Data

Hydraulic Rate - 8.0 GPM

Date	Sample	Influent ppm, COD	Tower Effluent ppm, COD	Final Effluent ppm, COD	Removal-Percent in Tower	Removal-Percent Total
Apr 10	8a-4p	389	200	156	48.6	59.9
1956	4p-12M	444	174	180	60.8	59.5
Apr 11	12M-8a	354	170	159	52.0	55.1
	8a-4p	341	195	125	42.8	63.4
	4p-12M	388	197	131	49.2	66.2
Apr 12	12M-8a	313	177	119	43.5	62.0
	8a-4p	406	247	147	39.2	63.8
	4p-12M	400	211	131	47.3	67.3
Apr 13	12M-8a	333	181	167	45.7	49.9
	8a-4p	405	200	167	50.6	58.8
	4p-12M	393	206	143	47.6	63.6
Apr 14	12M-8a	347	192	131	44.7	62.3
	8a-4p	276	161	83	41.7	69.9
	4p-12M	401	207	141	48.4	64.8
Apr 15	12M-8a	340	144	88	57.7	74.1
Apr 17	8a-4p	462	226	115	51.1	75.1
	4p-12M	453	221	175	51.2	61.4
Apr 18	12M-8a	389	185	157	52.5	59.7
	8a-4p	417	206	133	50.6	68.1
	4p-12M	376	157	125	58.3	66.8
Apr 19	12M-8a	351	144	136	59.0	61.3
	8a-4p	468	220	193	53.0	58.8
	4p-12M	512	238	215	53.5	58.0
Apr 20	12M-8a	435	205	224	52.9	48.5
	8a-4p	315	115	77	63.5	75.6
	4p-12M	450	139	129	69.1	71.3
Apr 21	12M-8a	369	235	112	36.3	69.7
	8a-4p	430	223	221	48.1	48.6
	4p-12M	489	336	208	31.3	57.5
Apr 22	12M-8a	575	303	294	47.3	48.9

Table A-6, Observed Summary Data at 8.0 GPM, Cont'd.

Date	Sample	Influent ppm, COD	Tower Effluent ppm, COD	Final Effluent ppm, COD	Removal-Percent	
					in Tower	Total
Apr 24	8a-4p	460	223	---	51.5	--
1956	4p-12M	486	249	275	48.8	43.4
Apr 25	12M-8a	509	233	191	54.2	62.5
	8a-4p	425	211	115	50.4	73.0
	4p-12M	570	250	208	56.2	63.5
Apr 26	12M-8a	371	156	104	58.0	72.0
	8a-4p	381	167	44	56.2	88.5
	4p-12M	407	169	82	58.5	79.9
Apr 27	12M-8a	358	154	34	57.0	90.5
	8a-4p	298	138	64	53.7	78.5
	4p-12M	370	147	103	60.3	72.2
Apr 28	12M-8a	291	71	64	75.6	78.0
	8a-4p	318	128	124	59.8	61.0
	4p-12M	306	129	64	57.9	79.1
Apr 29	12M-8a	287	99	60	65.5	79.1

Table A-7

Dowpac HCS Pilot Plant, Battle Creek, Michigan

Observed Summary Data

Hydraulic Rate - 3.1 GPM

Date-June 1956	Sample Time	Influent ppm, BOD	Settled Tower Effluent ppm, BOD	Percent Removal
11	8a-4p	253	38.0	85.0
	4p-12M	234	36.3	84.5
12	12M-8a	221	27.5	87.6
	8a-4p	243	28.5	88.3
	4p-12M	259	24.3	90.6
13	12M-8a	281	22.5	92.0
	8a-4p	298	33.3	88.8
	4p-12M	251	20.8	91.7
14	12M-8a	227	17.5	92.3
	8a-4p	260	24.8	90.5
	4p-12M	251	21.5	91.4
15	12M-8a	221	24.0	89.2
	8a-4p	223	24.5	89.0
	4p-12M	249	22.8	90.9
16	12M-8a	212	24.0	88.7
	8a-4p	285	31.4	89.0
	4p-12M	221	42.2	80.9
17	12M-8a	183	39.4	78.5
	8a-4p	200	48.0	76.0
	4p-12M	223	45.8	79.5
18	12M-8a	168	39.8	76.3
	8a-4p	172	55.7	67.6
	4p-12M	222	51.5	76.8
19	12M-8a	157	54.7	65.2
	8a-4p	210	44.2	79.0
	4p-12M	229	40.5	82.3
20	12M-8a	200	28.5	85.8
	8a-4p	195	26.8	86.3
	4p-12M	182	18.8	89.7
21	12M-8a	203	18.0	91.1
	8a-4p	280	34.8	87.6
	4p-12M	241	30.0	87.6

Table A-7, Reduction in BOD, 3.1 GPM, Cont'd.

Date-June 1956	Sample Time	Influent ppm, BOD	Settled Tower Effluent ppm, BOD	Percent Removal
22	12M-8a	190	21.8	88.5
	8a-4p	257	52.0	79.8
	4p-12M	228	19.2	91.6
23	12M-8a	208	13.7	93.4
	8a-4p	263	34.3	87.0
	4p-12M	254	17.5	93.1
24	12M-8a	198	11.5	94.2
	8a-4p	175	15.6	91.1
	4p-12M	196	22.1	88.7
25	12M-8a	58.7	20.0	65.9
	8a-4p	173	24.9	85.6
	4p-12M	217	20.3	90.7
26	12M-8a	173	16.4	90.5
	8a-4p	195	27.4	86.0
	4p-12M	229	24.0	89.5
27	12M-8a	205	22.3	89.1

Table A-8

Mean Daily Reduction in Biochemical and Chemical Oxygen Demand

(Based on 8-Hour Composites)

Hydraulic Rate - 33.1 GPM

Date Feb. 1956	Determination	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Lab.* Settled Effluent ppm	Percent in Tower	Removal Total	With Lab Settling
3-4	BOD	---	252	---	---	---	---	---
	COD	533	466	448	---	12.6	16.0	---
4-5	BOD	188	140	124	---	25.5	34.0	---
	COD	362	281	249	---	22.4	31.2	---
5-6	BOD	146	135	93	---	7.5	36.3	---
	COD	332	262	218	---	21.1	34.3	---
6-7	BOD	309	242	---	---	21.7	---	---
	COD	583	440	419	---	24.5	28.1	---
7-8	BOD	273	222	192	---	18.7	29.7	---
	COD	525	442	395	---	15.8	24.8	---
8-9	BOD	251	188	159	---	25.1	36.7	---
	COD	507	420	323	---	17.2	36.3	---
9-10	BOD	269	196	181	---	27.1	32.7	---
	COD	492	419	360	---	14.8	26.8	---
10-11	BOD	314	231	206	156	26.4	34.4	50.3
	COD	504	378	314	313	25.0	37.7	37.9
11-12	BOD	201	154	134	96.9	23.4	33.3	51.8
	COD	349	300	251	177	14.1	28.1	49.3
12-13	BOD	165	127	88	67.2	23.0	46.7	59.3
	COD	303	271	205	148	10.6	33.4	51.2
13-14	BOD	308	239	205	180	22.4	33.4	41.6
	COD	500	413	347	291	17.4	30.6	41.8
14-15	BOD	265	238	208	159	10.2	21.5	40.0
	COD	446	393	350	253	11.9	21.5	43.3
15-16	BOD	263	198	175	135	24.7	33.4	48.7
	COD	440	369	307	243	16.1	30.2	44.8
16-17	BOD	283	219	180	156	22.6	36.4	44.9
	COD	473	404	333	257	14.6	29.6	45.7

*600 ML Composite of 3 eight hour samples settled for one hour in a 500 ML graduated cylinder and top 300 ML decanted for analysis.

Table A-9

Mean Daily Reduction in Biochemical and Chemical Oxygen Demand

(Based on 8-Hour Composites)

Hydraulic Rate - 15.9 GPM

Date Feb. 1956	Determination	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Tower Effluent Settled ppm	Percent Removal		
						in Tower	Total	With Lab Settling
17-18	BOD	310	181	151	124	41.6	51.3	60.0
	COD	496	336	259	257	32.3	47.8	48.2
	Ratio*	0.625	0.539	0.583	0.482	--	--	--
18-19	BOD	163	127	93	61	22.1	42.9	62.6
	COD	285	248	173	162	13.0	39.3	43.2
	Ratio	0.572	0.512	0.538	0.377	--	--	--
19-20	BOD	183	108	69	--	41.0	62.3	--
	COD	319	221	154	--	30.7	51.7	--
	Ratio	0.574	0.489	0.448	--	--	--	--
20-21	BOD	317	202	181	128	36.3	42.9	59.7
	COD	516	382	344	268	26.0	33.4	48.1
	Ratio	0.614	0.529	0.526	0.478	--	--	--
21-22	BOD	270	197	188	136	27.0	30.4	49.7
	COD	461	366	354	267	20.6	23.2	42.2
	Ratio	0.586	0.538	0.531	0.509	--	--	--
22-23	BOD	281	217	153	142	22.8	45.6	49.5
	COD	473	400	295	278	15.4	37.6	41.2
	Ratio	0.594	0.543	0.519	0.511	--	--	--
23-24	BOD	278	167	115	90	39.9	58.7	67.7
	COD	469	296	228	202	36.9	51.3	56.9
	Ratio	0.593	0.564	0.504	0.446	--	--	--
24-25	BOD	208	131	98	---	37.0	52.8	--
	COD	392	271	202	---	30.9	48.5	--
	Ratio	0.531	0.483	0.485	---	--	--	--
25-26	BOD	217	131	123	71	39.6	43.3	67.3
	COD	358	240	242	157	33.0	32.4	56.2
	Ratio	0.606	0.546	0.508	0.452	--	--	--
26-27	BOD	153	77	49	36	49.7	68.1	76.4
	COD	257	157	123	116	38.9	52.1	54.9
	Ratio	0.595	0.490	0.398	0.310	--	--	--

* Ratio = $\frac{BOD}{COD}$

Table A-9, Mean Daily Reduction in BOD and COD, 15.9 GPM, Cont'd.

Date Feb. 1956	Determination	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Tower Effluent Settled ppm	Percent Removal		
						in Tower	Total	With Lab Settling
27-28	BOD	273	179	144	107	34.4	47.2	60.7
	COD	480	305	288	208	36.5	40.0	56.7
	Ratio	0.569	0.587	0.500	0.514	--	--	--
28-29	BOD	286	178	199	118	37.8	30.4	58.7
	COD	485	327	295	240	32.6	39.2	50.5
	Ratio	0.590	0.544	0.675	0.492	--	--	--
Feb 29 Mar 1	BOD	267	147	129	94	45.0	51.7	64.8
	COD	450	284	255	186	36.9	43.3	58.7
	Ratio	0.593	0.518	0.506	0.505	--	--	--
1-2	BOD	185	120	77	51	35.1	58.4	72.4
	COD	355	276	178	131	22.3	49.9	63.1
	Ratio	0.521	0.435	0.433	0.389	--	--	--
2-3	BOD	238	134	102	68	43.7	57.2	71.5
	COD	390	258	206	155	33.9	47.2	60.3
	Ratio	0.610	0.519	0.495	0.439	--	--	--
3-4	---	---	---	---	---	--	--	--
4-5	BOD	120	68	43	32	43.3	64.2	73.3
	COD	242	178	127	109	26.5	47.6	55.0
	Ratio	0.496	0.382	0.339	0.294	--	--	--
5-6	BOD	217	83	55	38	61.8	74.6	82.5
	COD	425	197	152	129	53.7	64.2	69.7
	Ratio	0.511	0.421	0.362	0.295	--	--	--
6-7	BOD	185	93	57	48	49.7	69.2	74.1
	COD	369	219	138	80	40.7	62.6	78.3
	Ratio	0.501	0.425	0.413	0.600	--	--	--
7-8	BOD	199	114	96	93	42.7	51.7	53.3
	COD	358	236	190	176	34.1	46.9	50.8
	Ratio	0.556	0.483	0.505	0.528	--	--	--
8-9	BOD	205	86	74	40	58.0	63.9	80.5
	COD	355	176	153	111	50.4	56.9	68.7
	Ratio	0.577	0.489	0.484	0.360	--	--	--
9-10	BOD	209	96	73	46	54.1	65.0	78.0
	COD	350	204	170	139	41.7	51.4	60.3
	Ratio	0.597	0.471	0.429	0.331	--	--	--

Table A-9, Mean Daily Reduction in BOD and COD, 15.9 GPM, Cont'd.

Date Mar. 1956	Determin-ation	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Tower Effluent Settled ppm	Percent Removal		
						in Tower	Total	With Lab Settling
10-11	---	---	---	---	---	--	--	--
11-12	BOD	119	63	38	26	47.1	68.1	78.2
	COD	249	168	111	118	32.5	55.4	52.6
	Ratio	0.478	0.375	0.342	0.220	--	--	--
12-13	BOD	224	102	68	47	54.5	69.7	79.0
	COD	408	262	190	153	35.8	53.4	62.5
	Ratio	0.549	0.389	0.358	0.307	--	--	--
13-14	BOD	220	105	59	47	52.3	73.2	78.7
	COD	406	263	161	161	35.2	60.4	60.4
	Ratio	0.542	0.399	0.366	0.292	--	--	--

Table A-10

Mean Daily Reduction in Chemical Oxygen Demand (COD)

(Based on 8-hour Composites)

Hydraulic Rate - 16 GPM Direct Plus 16 GPM Recirculation

Date-March 1956	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Lab. Settled Effluent ppm	Percent Removal Tower	Total	Lab Settled
20	634	423	309	241	33.3	51.3	62.0
21	429	300	217	200	30.1	49.4	53.4
22	425	325	201	159	23.5	52.7	62.6
23	514	352	266	254	31.5	48.3	50.6
24	359	252	211	216	29.8	41.2	39.8
27	437	328	237	245	25.0	45.8	43.9
28	372	247	174	154	33.6	53.2	58.6
29	402	265	204	176	34.1	49.3	56.2
30	358	272	207	147	24.0	42.2	58.9
31	330	227	154	165	31.2	53.3	50.0
April 3	493	356	211	213	27.8	57.2	56.8
4	398	249	175	168	37.4	56.0	57.8
5	401	289	166	176	27.9	58.6	56.1
6	396	267	177	184	32.6	55.3	53.5
7	347	252	183	190	27.4	47.3	45.3
Average Mean Daily Removals - March 20 to April 7					29.9	50.7	53.7

Table A-11

Mean Daily Reduction in Chemical Oxygen Demand (COD)

(Based on 8-Hour Composites)

Hydraulic Rate - 8 GPM

Date April 1956	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Tower Effluent Settled ppm	Percent Removal in Tower	Percent Removal Total	Percent Removal Lab Settled
10	396	181	165	156	54.3	58.3	60.6
11	347	190	125	117	45.3	64.0	66.3
12	380	213	148	139	44.0	61.1	63.4
13	382	199	147	121	47.9	61.5	68.3
14	339	171	104	114	49.6	69.3	66.4
17	435	211	149	146	51.5	65.8	66.4
18	381	169	131	86	55.7	65.6	77.4
19	472	221	211	178	53.2	55.3	62.3
20	378	163	106	92	56.9	72.0	75.7
21	498	297	241	183	40.4	51.6	63.3
24	485	235	233	130	51.6	52.0	73.2
25	455	206	142	129	54.7	68.8	71.7
26	382	163	53	26	57.3	86.1	93.2
27	320	119	77	58	62.8	75.9	81.9
28	304	119	83	143	60.9	72.7	53.0

Table A-12

Mean Daily Reduction in Biochemical Oxygen Demand (BOD)

(Based on 8-Hour Composites)

Hydraulic Rate - 3.1 GPM

Date-June 1956*	Influent ppm	Settled Tower Effluent ppm	Percent Removal
11-12	236	33.9	85.7
12-13	261	25.1	90.3
13-14	259	23.9	90.9
14-15	244	23.4	90.4
15-16	228	23.8	89.5
16-17	230	37.7	82.8
17-18	197	44.5	77.3
18-19	184	54.0	69.9
19-20	213	37.7	82.4
20-21	193	21.2	89.0
21-22	237	28.9	87.9
22-23	231	28.3	88.3
23-24	238	21.1	91.4
24-25	143	19.2	81.9
25-26	188	20.5	88.9
26-27	210	24.6	88.2
Average	218	29.2	85.9

*Sample time - 8:00 a.m. to 8:00 a.m.

Table A-13

Reduction in Biochemical Oxygen Demand (BOD)

(Based on 24-Hour Composites)

Hydraulic Rate - 16 GPM Direct Plus 16 GPM Recirculation

Date March 1956	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Lab. Settled Effluent ppm	Percent Removal		
					Tower	Total	Lab. Settled
20	370	185	140	104	50.0	62.2	71.9
21	233	150	84	80	35.6	64.0	65.7
22	249	115	81	61	53.8	67.5	75.5
23	241	211	107	110	12.5	55.6	54.4
24	194	122	90	72	37.1	53.6	62.9
27	215	172	121	114	20.0	43.7	47.0
28	229	109	75	65	52.4	67.3	71.6
29	236	125	90	72	47.0	61.9	69.5
30	205	114	80	59	44.4	61.0	71.2
31	197	100	68	62	49.2	65.5	68.5
April 3	320	162	106	94	49.4	66.9	70.6
4	235	116	77	71	50.6	67.2	69.8
5	248	132	80	75	46.8	67.8	69.8
6	227	115	75	75	49.3	67.0	67.0
7	212	119	81	76	43.9	61.8	64.2
Average from March 20 to April 7						62.2	66.6

Table A-14

Reduction in Chemical Oxygen Demand (COD)

(Based on 24-Hour Composites)

Hydraulic Rate - 16 GPM Direct Plus 16 GPM Recirculation

Date March 1956	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Lab. Settled Effluent ppm	Percent Removal		
					Tower	Total	Lab. Settled
20	605	456	294	241	24.6	51.4	60.2
21	415	309	212	200	25.6	48.9	51.8
22	405	273	171	159	32.6	57.8	60.8
23	404	431	260	254	----	35.7	37.1
24	353	251	224	216	28.9	36.6	38.8
27	439	321	235	245	26.9	46.5	44.2
28	377	230	184	154	39.0	51.2	59.2
29	398	244	201	176	38.7	49.5	55.8
30	355	240	201	147	32.4	43.4	58.6
31	296	210	138	165	29.1	53.4	44.3
April 3	484	337	211	213	30.4	56.4	56.0
4	390	249	166	168	36.2	57.4	56.9
5	380	252	146	176	33.7	61.6	53.7
6	335	247	172	184	26.3	48.7	45.1
7	337	255	201	190	24.3	40.4	43.6
Average from March 20 to April 24					30.6	49.3	51.1

Table A-15

Reduction in Biochemical Oxygen Demand (BOD)

(Based on 24-Hour Composites)

Hydraulic Rate - 8 GPM

Date April 1956	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Lab. Settled Effluent ppm	Percent Removal		
					Tower	Total	Lab. Settled
10	231	77	66	70	66.7	71.4	69.7
11	194	70	45	36	63.9	76.8	81.5
12	174	81	92	39	53.5	47.1	77.6
13	226	84	50	39	62.8	77.9	82.8
14	213	64	37	37	70.0	82.6	82.6
17	260	91	58	59	65.0	77.7	77.3
18	231	71	56	43	69.3	75.8	81.4
19	254	68	67	50	73.2	73.6	80.3
20	251	72	57	47	71.3	77.3	81.3
21	235	70	59	49	70.2	74.9	79.2
24	291	80	55	46	72.5	81.1	84.2
25	249	67	43	41	73.1	82.7	83.5
26	232	69	47	46	70.3	79.8	80.2
27	193	61	24	30	68.4	87.6	84.5
28	171	51	25	36	70.2	85.4	79.0

Table A-16

Reduction in Chemical Oxygen Demand (COD)

(Based on 24-Hour Composites)

Hydraulic Rate - 8 GPM

Date April 1956	Influent ppm	Tower Effluent ppm	Final Effluent ppm	Lab. Settled Effluent ppm	Percent Removal		
					Tower	Total	Lab. Settled
10	395	157	181	156	60.3	54.2	60.5
11	340	191	127	117	43.8	62.7	65.6
12	323	213	213	139	34.1	34.1	57.0
13	375	192	146	121	48.8	61.1	67.7
14	354	230	125	114	35.0	64.7	67.8
17	383	195	111	146	49.1	71.0	61.9
18	359	156	114	86	56.6	68.3	76.1
19	465	227	195	178	51.2	58.1	61.7
20	489	170	191	92	65.2	61.0	81.2
21	461	276	205	183	40.1	55.5	60.3
24	503	167	191	130	66.8	62.0	74.2
25	429	178	145	129	58.5	66.2	69.9
26	361	87	57	26	75.9	84.2	92.8
27	376	112	99	58	70.2	73.7	84.6
28	330	123	79	143	62.7	76.1	56.7

Table A-17

Reduction in Chemical and Biochemical Oxygen Demand

(Based on 24-Hour Composites)

Hydraulic Rate - 3.1 GPM

Date 1956	Determination	Influent ppm	Tower Effluent ppm	Lab. Settled Effluent ppm	Removal in Tower ppm	Percent Removal With Lab Settling
June 11	BOD	263	107	29.5	59.3	88.8
	COD	423	371	126	12.3	70.2
	Ratio	0.622	0.288	0.234	--	--
12	BOD	250	66.3	21.0	73.5	91.6
	COD	453	198	101	56.3	77.7
	Ratio	0.552	0.335	0.208	--	--
13	BOD	278	78.7	23.3	71.7	91.6
	COD	472	244	98.0	48.3	79.2
	Ratio	0.589	0.323	0.238	--	--
14	BOD	240	97.3	23.0	59.5	90.4
	COD	424	269	93.0	36.6	78.1
	Ratio	0.566	0.362	0.247	--	--
15	BOD	233	96.3	23.0	58.7	90.1
	COD	425	279	103	34.4	75.8
	Ratio	0.548	0.345	0.223	--	--
16	BOD	223	169	41.0	24.2	81.6
	COD	382	496	124	-29.9	67.5
	Ratio	0.584	0.341	0.331	--	--
17	BOD	202	176	46.2	12.9	77.1
	COD	344	486	137	-37.2	60.2
	Ratio	0.587	0.362	0.337	--	--
18	BOD	180	237	49.5	-31.6	72.5
	COD	321	711	166	-121	48.3
	Ratio	0.561	0.333	0.298	--	--
19	BOD	205	117	37.0	42.9	82.0
	COD	421	379	129	10.0	69.4
	Ratio	0.487	0.309	0.287	--	--
20	BOD	187	78.3	21.8	58.1	88.4
	COD	372	340	110	8.6	70.4
	Ratio	0.503	0.230	0.198	--	--

Table A-17, Reduction in COD and BOD, 3.1 GPM, Cont'd.

Date 1956	Determination	Influent ppm	Tower Effluent ppm	Lab. Settled Effluent ppm	Removal in Tower ppm	Percent Removal With Lab Settling
June 21	BOD	236	79.3	27.7	66.4	88.3
	COD	397	255	96.0	35.8	75.8
	Ratio	0.594	0.311	0.289	--	--
22	BOD	231	63.0	25.7	72.7	88.9
	COD	393	202	101	48.6	74.3
	Ratio	0.588	0.312	0.254	--	--
23	BOD	231	57.3	21.0	75.2	90.9
	COD	395	153	78.0	61.3	80.3
	Ratio	0.585	0.375	0.269	--	--
24	BOD	149	45.3	17.4	69.6	88.3
	COD	280	105	70.0	62.5	75.0
	Ratio	0.532	0.431	0.249	--	--
25	BOD	182	32.3	19.5	82.3	89.3
	COD	382	132	88.0	65.5	77.0
	Ratio	0.476	0.245	0.222	--	--
26	BOD	204	66.5	25.5	67.4	87.5
	COD	401	183	97.0	54.4	75.8
	Ratio	0.509	0.363	0.263	--	--
Ave.	BOD	218	97.9	28.3	--	86.7
	COD	393	300	107	--	72.2
	Ratio	0.555	0.329	0.259	--	--

Table A-18

Dowpac HCS Tower Performance with Tank Compared with Lab Settling at a Hydraulic Rate of 33.1 GPM

Basis: 5-day Biochemical Oxygen Demand

Date Feb. 1956	5-day B.O.D. Influent ppm	Load Applied Lb./1000 ft^3/day	Performance With Tank Percent Reduction	Performance With Tank Percent Remaining	Performance with Lab Settling Percent Reduction	Performance with Lab Settling Percent Remaining
4-5	188	183	34.0	66.0	--	--
5-6	146	142	36.3	63.7	--	--
6-7	309	300	--	--	--	--
7-8	273	265	29.7	70.3	--	--
8-9	251	244	36.7	63.3	--	--
9-10	269	261	32.7	67.3	--	--
10-11	314	305	34.4	65.6	50.3	49.7
11-12	201	195	33.3	66.7	51.8	48.2
12-13	165	160	46.7	53.3	59.3	40.7
13-14	308	299	33.4	66.6	41.6	58.4
14-15	265	257	21.5	78.5	40.0	60.0
15-16	263	255	33.4	66.6	48.7	51.3
16-17	283	275	36.4	63.6	44.9	55.1

*Influent B.O.D. based on mean of three 8-hour composites

Effluent B.O.D. based on 24-hour composites

Table A-19

Loading and Performance at 15.9 GPM Based on the Final Settling Tank Effluent*

Basis: 5-day Biochemical Oxygen Demand

	5-day B.O.D.		Performance-Percent	
Date 1956	Influent ppm	Load Applied Lb./1000 ft^3/day	Reduction	Remaining
Feb.				
17-18	310	144	51.3	48.7
18-19	163	76	42.9	57.1
19-20	183	85	62.3	37.7
20-21	317	148	42.9	57.1
21-22	270	126	30.4	69.6
22-23	281	131	45.6	54.4
23-24	278	129	58.7	41.3
24-25	208	97	52.8	47.2
25-26	217	101	43.3	56.7
26-27	153	71	68.1	31.9
27-28	273	127	47.2	52.8
28-29	286	133	30.4	69.6
Feb 29 Mar 1	267	124	51.7	48.3
Mar 1-2	185	86	58.4	41.6
2-3	238	111	57.2	42.8
4-5	120	56	64.2	35.8
5-6	217	101	74.6	25.4
6-7	185	86	69.2	30.8
7-8	199	93	51.7	48.3
8-9	205	95	63.9	36.1
9-10	209	97	65.0	35.0
11-12	119	55	68.1	31.9
12-13	224	104	69.7	30.3
13-14	220	102	73.2	26.8

*Means of three 8-hour composites

Table A-20

Dowpac HCS Tower Performance with Tank Compared with Laboratory Settling at a Hydraulic Rate of 15.9 GPM*

Basis: 5-day Biochemical Oxygen Demand

Date	5-day B.O.D.		Performance With Tank Percent		Performance With Lab Settling-Percent	
March 1956	Influent ppm	Load Applied Lb./1000 ft^3/day	Removed	Remaining	Reduction	Remaining
2	166	77.2	65.7	34.3	69.5	30.5
3	205	95.4	58.5	41.5	66.8	33.2
5	102	47.4	65.7	34.3	68.6	31.4
6	204	95.0	79.4	20.6	81.4	18.6
7	158	73.5	72.2	27.8	69.6	30.4
8	264	122.5	67.9	32.1	64.8	35.2
9	186	86.5	70.5	29.5	78.5	21.5
10	190	88.3	67.4	32.6	75.8	24.2
12	96	44.6	64.6	35.4	63.1	36.9
13	196	91.0	75.0	25.0	76.0	24.0
14	202	94.0	75.3	24.7	76.7	23.3

*Based on 24-hour composites, 5-day B.O.D.

Table A-21

Performance with Tank Compared with Laboratory Settling at a Hydraulic Rate of 8.0 GPM*

Basis: 5-day Biochemical Oxygen Demand

Date	5-day B.O.D.		Performance With Tank Percent		Performance With Lab Settling-Percent	
April 1956	Influent ppm	Load Applied Lb./1000 ft^3/day	Removed	Remaining	Reduction	Remaining
10-11	231	54.3	71.4	28.6	69.7	30.3
11-12	194	45.6	76.8	23.2	81.5	18.5
12-13	174	40.9	47.1	52.9	77.6	22.4
13-14	226	53.1	77.9	22.1	82.8	17.2
14-15	213	50.1	82.6	17.4	82.6	17.4
17-18	260	61.1	77.7	22.3	77.3	22.7
18-19	231	54.3	75.8	24.2	81.4	18.6
19-20	254	59.7	73.6	26.4	80.3	19.7
20-21	251	59.0	77.3	22.7	81.3	18.7
21-22	235	55.2	74.9	25.1	79.2	20.8
24-25	291	68.5	81.1	18.9	84.2	15.8
25-26	249	58.5	82.7	17.3	83.5	16.5
26-27	232	54.6	79.8	30.2	80.2	19.8
27-28	193	45.4	87.6	12.4	84.5	15.5
28-29	171	40.2	85.4	14.6	79.0	21.0

*Based on 24-hour composites, 5-day B.O.D.

Table A-22

Dowpac HCS Tower Performance at a Hydraulic Rate of 16 GPM Direct (Nominal)**

Plus 16 GPM Recirculation*

Basis: 5-day Biochemical Oxygen Demand

Date 1956	BOD-ppm Tower		BOD-ppm Effluents		Influent	Organic Application Rate lb. BOD/1000 ft^3/day			Tower Performance-Percent		Performance With Tank Percent	
March	Influent	Effluent	Tank	Lab Settled	Factor**	Influent	Recirculant	Total	Reduction	Remaining	Reduction	Remaining
20-21	370	185	140	104	12.30 GPM = .3609	134	87	221	50.0	50.0	62.2	37.8
21-22	233	150	84	80	12.60 GPM = .3697	86	70	156	35.6	64.4	64.0	36.0
22-23	249	115	81	61	12.40 GPM = .3638	91	54	145	53.8	46.2	67.5	32.5
23-24	241	211	107	110	12.40 GPM = .3638	88	99	187	12.5	87.5	55.6	44.4
24-25	194	122	90	72	15.50 GPM = .4548	88	57	145	37.1	62.9	53.6	46.4
27-28	215	172	121	114	16.20 GPM = .4753	102	81	183	20.0	80.0	43.7	56.3
28-29	229	109	75	65	15.45 GPM = .4533	104	51	155	52.4	47.6	67.3	32.7
29-30	236	125	90	72	12.20 GPM = .3580	84	59	143	47.0	53.0	61.9	38.1
30-31	205	114	80	59	12.50 GPM = .3668	75	54	129	44.4	55.6	61.0	39.0
Mar 31 Apr 1	197	100	68	62	16.30 GPM = .4783	94	47	141	49.2	50.8	65.5	34.5
3-4	320	162	106	94	16.30 GPM = .4783	153	76	229	49.4	50.6	66.9	33.1
4-5	235	116	77	71	16.20 GPM = .4753	112	54	166	50.6	49.4	67.2	32.8
5-6	248	132	80	75	16.00 GPM = .4695	116	62	178	46.8	53.2	67.8	32.2
6-7	227	115	75	75	14.58 GPM = .4278	97	54	151	49.3	50.7	67.0	33.0
7-8	212	119	81	76	15.77 GPM = .4627	98	56	154	43.9	56.1	61.8	38.2

*Recirculant - Unsettled tower effluent

**Recirculant factor = 0.4695 (16 GPM); variation in influent rate attributed to pump-bearing failure.

Table A-23

Dowpac HCS Tower Performance at a Hydraulic Rate of 3.1 GPM

Based on Mean of Three 8-Hour Composites					Based on 24-Hour Composites				
	5-day B.O.D.					5-day B.O.D.			
Date June 1956	Influent Conc.-ppm	Applied Load*-Lb/-1000 ft^3/day	Performance-Percent Reduction	Performance-Percent Remaining	June 1956	Influent Conc.-ppm	Applied Load*-Lb/-1000 ft^3/day	Performance-Percent Reduction	Performance-Percent Remaining
11-12	236	21.5	85.7	14.3	11	263	23.9	88.8	11.2
12-13	261	23.8	90.3	9.7	12	250	22.8	91.6	8.4
13-14	259	23.6	90.9	9.1	13	278	25.3	91.6	8.4
14-15	244	22.2	90.4	9.6	14	240	21.8	90.4	9.6
15-16	228	2[illegible]	89.5	10.5	15	233	21.2	90.1	9.9
16-17	230	20.[illegible]	82.8	17.2	16	223	20.3	81.6	18.4
17-18	197	17.9	77.3	22.7	17	202	18.4	77.1	22.9
18-19	184	16.7	69.9	30.1	18	180	16.4	72.5	27.5
19-20	213	19.4	82.4	17.6	19	205	18.7	82.0	18.0
20-21	193	17.6	89.0	11.0	20	187	17.0	88.4	11.6
21-22	237	21.6	87.9	12.1	21	236	21.5	88.3	11.7
22-23	231	21.0	88.3	11.7	22	231	21.0	88.9	11.1
23-24	238	21.7	91.4	8.6	23	231	21.0	90.9	9.1
24-25	143	13.0	81.9	18.1	24	149	13.6	88.3	11.7
25-26	168	17.1	88.9	11.1	25	182	16.6	89.3	10.7
26-27	210	19.1	88.2	11.8	26	204	18.6	87.5	12.5
Av.	218	19.9	85.9	14.1	Ave.	218	19.9	86.7	13.3

*Factor (f) = 0.0910 in: Load (lb/1000 ft^3/day) = Concentration x (f)

Table A-24

Dowpac HCS Tower Performance With Tank Compared With Laboratory Settling

at a Hydraulic Rate of 33.1 GPM

Basis - Chemical Oxygen Demand

Date Feb. 1956	Chemical Oxygen Demand Influent ppm	Chemical Oxygen Demand Load Applied- Lb/1000 ft^3/day*	Performance With Tank (Percent) Reduction	Performance With Tank (Percent) Remaining	Performance With Laboratory Settling-Percent Reduction	Performance With Laboratory Settling-Percent Remaining
3-4	533	518	16.0	84.0	--	--
4-5	362	352	31.2	68.8	--	--
5-6	332	322	34.3	65.7	--	--
6-7	583	566	28.1	71.9	--	--
7-8	525	510	24.8	75.2	--	--
8-9	507	492	36.3	63.7	--	--
9-10	492	478	26.8	73.2	--	--
10-11	504	490	37.7	62.3	37.9	62.1
11-12	349	339	28.1	71.9	49.3	50.7
12-13	303	294	33.4	66.6	51.2	48.8
13-14	500	486	30.6	69.4	41.8	58.2
14-15	446	433	21.5	78.5	43.3	56.7
15-16	440	427	30.2	69.8	44.8	55.2
16-17	473	459	29.6	70.4	45.7	54.3

*Factor (f) = 0.9713 in: Load (lb/1000 ft^3/day) = Concentration x (f)
Influent based on mean of three 8-hour composites
Effluent based on 24-hour composite

Table A-25

Dowpac HCS Tower Performance at a Hydraulic Rate of 15.9 GPM

Basis: Chemical Oxygen Demand - Final Tank Effluent

Date 1956 Feb.	Chemical Oxygen Demand*		Performance-Percent	
	Influent ppm	Load Applied ** Lb/1000 ft^3/day	Reduction	Remaining
17-18	496	231	47.8	52.2
18-19	285	133	39.3	60.7
19-20	319	149	51.7	48.3
20-21	516	240	33.4	66.6
21-22	461	215	23.2	76.8
22-23	473	220	37.6	62.4
23-24	469	218	51.3	48.7
24-25	392	183	48.5	51.5
25-26	358	167	32.4	67.6
26-27	257	120	52.1	47.9
27-28	480	224	40.0	60.0
28-29	485	226	39.2	60.8
Feb 29 Mar 1	450	210	43.3	56.7
1-2	355	165	49.9	50.1
2-3	390	182	47.2	52.8
4-5	242	113	47.6	52.4
5-6	425	198	64.2	35.8
6-7	369	172	62.6	37.2
7-8	358	167	46.9	53.1
8-9	355	165	56.9	43.1
9-10	350	163	51.4	48.6
11-12	249	116	55.4	44.6
12-13	408	190	53.4	46.6
13-14	406	189	60.4	39.6

* Based on mean of three 8-hour composites

**(f) = 0.4657 in: Load (lb/1000 ft^3/day) = Concentration x (f)

Table A-26

Dowpac HCS Tower Performance with Tank Compared with Laboratory Settling

at a Hydraulic Rate of 15.9 GPM

Basis: Chemical Oxygen Demand*

Date March 1956	Chemical Influent ppm	Oxygen Demand Applied Load** Lb/1000 ft3/day	Performance With Tank (Percent) Reduction	Performance With Tank (Percent) Remaining	Performance With Lab Settling-Percent Reduction	Performance With Lab Settling-Percent Remaining
2	328	153	49.7	50.3	--	--
3	359	167	45.0	55.0	56.9	43.1
5	242	113	53.4	46.6	--	--
6	410	191	66.6	33.4	68.5	31.5
7	304	142	59.0	41.0	73.7	26.3
8	317	148	43.0	51.0	44.5	55.5
9	358	167	57.6	42.4	69.0	31.0
10	357	166	52.7	47.3	61.0	39.0
12	240	112	49.3	50.7	50.8	49.2
13	374	174	43.8	56.2	59.0	41.0
14	393	183	56.2	43.8	59.0	41.0

*Based on 24-hour composites

** (f) = 0.4657 in: Load (lb/1000 ft^3/day) = Concentration x (f)

Table A-27

Dowpac HCS Tower Performance with Tank Compared with Laboratory Settling

at a Hydraulic Rate of 8.0 GPM

Basis: Chemical Oxygen Demand*

Date	Chemical Oxygen Demand		Performance With Tank (Percent)		Performance With Lab Settling-Percent	
April 1956	Influent ppm	Applied Load** Lb/1000 ft^3/day	Reduction	Remaining	Reduction	Remaining
10-11	396	93	58.3	41.7	60.6	39.4
11-12	347	82	64.0	36.0	66.3	33.7
12-13	380	89	61.1	38.9	63.4	36.4
13-14	382	90	61.5	38.5	68.3	31.7
14-15	339	80	69.3	30.7	66.4	33.6
17-18	435	102	65.8	34.2	66.4	33.6
18-19	381	89	65.6	34.4	77.4	22.6
19-20	472	111	55.3	44.7	62.3	37.6
20-21	378	89	72.0	28.0	75.7	24.3
21-22	498	117	51.6	48.4	63.3	36.7
24-25	485	114	52.0	48.0	73.2	26.8
25-26	455	107	68.8	31.2	71.7	28.3
26-27	382	90	86.1	13.9	73.2	26.8
27-28	320	75	75.9	24.1	81.2	18.8
28-29	304	71	72.7	27.3	53.0	47.0

*Based on mean of three 8-hour composites

**(f) = 0.2349 in: Load (lb/1000 ft^3/day) = Concentration x (f)

Table A-28

Dowpac HCS Tower Performance with Tank Compared with Laboratory Settling

at a Hydraulic Rate of 8.0 GPM

Basis: Chemical Oxygen Demand*

Date April 1956	Chemical Oxygen Demand		Performance With Tank (Percent)		Performance With Lab Settling-Percent	
	Influent ppm	Applied Load** Lb/1000 ft^3/day	Reduction	Remaining	Reduction	Remaining
10	395	92.5	54.2	45.8	60.5	39.5
11	340	79.6	62.7	37.3	65.6	34.4
12	323	75.8	34.1	65.9	57.0	43.0
13	375	88.0	61.1	38.9	67.7	32.3
14	354	83.1	64.7	35.3	67.8	32.2
17	383	90.0	71.0	29.0	61.9	38.1
18	359	84.1	68.3	31.7	76.1	23.9
19	465	109	58.1	41.9	61.7	38.3
20	489	115	61.0	39.0	81.2	18.8
21	461	108	55.5	44.5	60.3	39.7
24	503	118	62.0	38.0	74.2	25.8
25	429	101	66.2	33.8	69.9	30.1
26	361	84.5	84.2	15.8	92.8	7.2
27	376	88.2	73.7	26.3	84.6	15.4
28	330	77.5	76.1	23.9	56.7	43.3
Mean			63.5		69.2	

* Based on 24-hour composites

**(f) = 0.2349 in: Load (lb/1000 ft^3/day) = Concentration x (f)

Table A-29

Dowpac HCS Tower Performance at a Hydraulic Rate 16 GPM Direct (Nominal)**

Plus 16 GPM Recirculation*

Basis: Chemical Oxygen Demand

Date 1956 March	COD-ppm Tower Influent	COD-ppm Tower Effluent	COD-ppm Effluents Tank	COD-ppm Effluents Lab Settled	Influent Factor**	Organic Application Rate lb. COD/1000 ft^3/day Influent	Organic Application Rate lb. COD/1000 ft^3/day Recirculant	Organic Application Rate lb. COD/1000 ft^3/day Total	Tower Performance-Percent Reduction	Tower Performance-Percent Remaining	Performance With Tank Percent Reduction	Performance With Tank Percent Remaining
20-21	634	423	309	241	12.30 GPM $f = .3609$	229	199	428	33.3	66.7	51.3	48.7
21-22	429	300	217	200	12.60 GPM $f = .3697$	159	141	300	30.1	69.9	49.4	50.6
22-23	425	325	201	159	12.40 GPM $f = .3638$	155	153	308	23.5	76.5	52.7	47.3
23-24	514	352	266	254	12.40 GPM $f = .3638$	187	165	352	31.5	68.5	48.3	51.7
24-25	359	252	211	216	15.50 GPM $f = .4548$	163	118	281	29.8	70.2	41.2	58.8
27-28	437	328	237	245	16.20 GPM $f = .4753$	208	154	352	25.0	75.0	45.8	54.2
28-29	372	247	174	154	15.45 GPM $f = .4533$	169	116	285	33.6	66.4	53.2	46.8
29-30	402	265	204	176	12.20 GPM $f = .3580$	144	124	268	34.1	65.9	49.3	50.7
30-31	358	272	207	147	12.50 GPM $f = .3668$	131	128	259	24.0	76.0	42.2	57.8
Mar 31 Apr 1	330	227	154	165	16.30 GPM $f = .4783$	158	107	265	31.2	68.8	53.3	46.7
3-4	493	356	211	213	16.30 GPM $f = .4783$	236	167	403	27.8	72.2	57.2	42.8
4-5	398	249	175	168	16.20 GPM $f = .4753$	189	117	306	37.4	62.6	56.0	44.0
5-6	401	289	166	176	16.00 GPM $f = .4695$	188	136	324	27.9	72.1	58.6	41.4
6-7	396	267	177	184	14.58 GPM $f = .4278$	169	125	294	32.6	67.4	55.3	44.7
7-8	347	252	183	190	15.77 GPM $f = .4627$	161	118	279	27.4	72.6	47.3	52.7

* Recirculant - Unsettled tower effluent

**Recirculant factor = 0.4695 (16 GPM); Variation in influent rate attributed to pump bearing failure.

Table A-30

Dowpac HCS Tower Performance at a Hydraulic Rate of 3.1 GPM

Basis: Chemical Oxygen Demand*

Date June 1956	Chemical Oxygen Demand-ppm	Effluents		COD Loading**	Tower Performance-Percent		Performance with Lab Settling-Percent	
	Influent	Tower	Lab Settled	Lb/1000 ft^3/day	Reduction	Remaining	Reduction	Remaining
11	423	371	126	38.5	12.3	87.7	70.2	29.8
12	453	198	101	41.2	56.3	43.7	77.7	22.3
13	472	244	98.0	43.0	48.3	51.7	79.2	20.8
14	424	269	93.0	38.6	36.6	63.4	78.1	21.9
15	425	279	103	38.7	34.4	65.6	75.8	24.2
16	382	496	124	34.8	-29.9	129.9	67.5	32.5
17	344	486	137	31.3	-37.2	137.2	60.2	39.8
18	321	711	166	29.2	-121	221	48.3	51.7
19	421	379	129	38.3	10.0	90.0	69.4	30.6
20	372	340	110	33.9	8.6	91.4	70.4	29.6
21	397	255	96.0	36.1	35.8	64.2	75.8	24.2
22	393	202	101	35.8	48.6	51.4	74.3	25.7
23	395	153	78.0	35.9	61.3	38.7	80.3	19.7
24	280	105	70.0	25.5	62.5	37.5	75.0	25.0
25	382	132	88.0	34.8	65.5	34.5	77.0	23.0
26	401	183	97.0	36.5	54.4	45.6	75.8	24.2
Mean	393	300	107	35.8	--	--	72.2	27.8

* Based on 24-hour composites

**(f) = 0.0910 in: Load (lb/1000 ft^3/day) = Concentration x (f)

Table A-31

Dowpac HCS Pilot Plant

Relationship of Performance to Depth at a Hydraulic Rate of 33.1 GPM

Date Feb. 1956	Determin-ation	Influent	10.5' ppm	Depth* %R**	21' ppm	Depth* %R**	31.5' ppm	Depth* %R**	42' ppm	Depth* %R**	Final ppm	Effluent* %R**
11	BOD	321	287	10.6	285	11.2	288	10.3	268	16.5	216	32.7
	COD	420	371	11.7	361	14.1	379	9.8	357	15.0	270	35.7
	Ratio	0.765	0.772	--	0.787	--	0.761	--	0.735	--	0.800	--
12	BOD	174	145	16.7	134	23.0	120	31.0	117	32.8	77.8	55.3
	COD	285	264	7.4	335	0	248	13.0	240	15.8	184	35.4
	Ratio	0.611	0.550	--	0.400	--	0.483	--	0.450	--	0.423	--
13	BOD	166	169	0	146	12.1	142	14.5	127	23.5	95.9	42.2
	COD	318	298	6.3	293	7.9	277	12.9	271	14.8	210	34.0
	Ratio	0.522	0.558	--	0.497	--	0.512	--	0.469	--	0.458	--
14	BOD	381	379	0.5	346	9.2	337	11.6	313	17.9	248	34.9
	COD	576	563	2.3	513	10.9	515	10.6	474	17.7	379	34.2
	Ratio	0.646	0.677	--	0.674	--	0.655	--	0.661	--	0.652	--
15	BOD	282	254	9.9	245	13.1	238	15.6	192	31.9	190	32.6
	COD	446	417	6.5	410	8.1	379	15.0	385	13.7	312	30.0
	Ratio	0.663	0.612	--	0.598	--	0.662	--	0.498	--	0.609	--
16	BOD	244	213	12.7	202	17.2	187	23.4	184	24.6	147	39.8
	COD	392	361	7.9	339	13.5	315	19.7	332	15.3	250	36.2
	Ratio	0.623	0.590	--	0.596	--	0.593	--	0.554	--	0.588	--
17	BOD	251	253	0	258	0	248	1.2	212	15.5	175	30.3
	COD	401	384	4.2	391	2.5	360	10.2	337	16.0	283	29.4
	Ratio	0.627	0.659	--	0.660	--	0.690	--	0.630	--	0.618	--

* Representative samples not laboratory settled
**Percent Removal

Table A-32

Dowpac HCS Pilot Plant

Relationship of Performance to Depth at a Hydraulic Rate of 15.9 GPM

Date Feb. 1956	Determin-ation	Influent	10.5' Depth		21' Depth		31.5' Depth		42' Depth		Final Effluent	
			ppm	%R*	ppm	%R*	ppm	%R*	ppm	%R*	ppm	%R*
18**	BOD	364	315	13.5	278	23.6	249	31.6	222	39.0	174	52.2
	COD	578	496	14.2	439	24.1	394	31.8	376	35.0	301	47.9
	Ratio	0.630	0.635	--	0.633	--	0.632	--	0.590	--	0.578	--
19	BOD	93	82	11.8	66	29.0	59	36.6	54	41.9	49	47.3
	COD	186	170	8.6	146	21.5	120	35.5	131	29.6	111	40.3
	Ratio	0.500	0.482	--	0.452	--	0.492	--	0.412	--	0.441	--
20	BOD	165	130	21.2	97	41.2	74	55.2	71	57.0	60	63.6
	COD	273	223	18.3	186	31.9	161	41.0	158	42.1	136	50.2
	Ratio	0.604	0.583	--	0.522	--	0.460	--	0.449	--	0.441	--
21	BOD	294	267	9.2	231	21.4	200	32.0	177	39.8	158	46.3
	COD	479	418	12.7	371	22.6	347	27.6	305	36.3	272	43.2
	Ratio	0.614	0.639	--	0.623	--	0.576	--	0.580	--	0.581	--
22	BOD	239	212	11.3	195	18.4	175	26.8	151	36.8	142	40.6
	COD	400	341	14.8	314	21.5	300	25.0	251	37.5	263	34.3
	Ratio	0.733	0.622	--	0.621	--	0.583	--	0.602	--	0.540	--
23	BOD	297	251	15.5	206	30.6	207	30.3	168	43.4	150	49.5
	COD	452	377	16.6	322	28.8	315	30.3	277	38.7	254	43.8
	Ratio	0.657	0.666	--	0.640	--	0.657	--	0.606	--	0.591	--
24	BOD	300	266	11.3	234	22.0	179	40.3	143	52.3	131	56.3
	COD	448	399	10.9	363	19.0	281	37.3	244	45.5	231	48.4
	Ratio	0.670	0.667	--	0.645	--	0.637	--	0.586	--	0.567	--
25	BOD	233	186	20.2	157	32.6	149	36.1	115	50.7	109	53.2
	COD	403	256	36.5	318	21.1	237	41.2	214	46.9	199	50.6
	Ratio	0.578	0.727	--	0.494	--	0.629	--	0.537	--	0.548	--
26	BOD	170	121	28.8	115	32.4	94	44.7	75	55.9	66	61.2
	COD	262	211	19.5	198	24.4	166	36.7	144	45.0	149	43.1
	Ratio	0.649	0.573	--	0.581	--	0.566	--	0.521	--	0.443	--

Table A-32, Relationship of Performance to Depth at 15.9 GPM, Cont'd.

Date Feb. 1956	Determination	Influent	10.5' ppm	Depth %R*	21' ppm	Depth %R*	31.5' ppm	Depth %R*	42' ppm	Depth %R*	Final ppm	Effluent %R*
27	BOD	117	86	26.5	60	48.7	49	58.1	36	69.2	33	71.8
	COD	198	150	24.3	127	35.9	111	43.9	94	52.5	89	55.1
	Ratio	0.590	0.573	--	0.472	--	0.441	--	0.383	--	0.371	--
28	BOD	268	221	17.5	181	32.5	167	37.7	134	50.0	124	53.7
	COD	436	347	20.4	293	32.8	274	37.2	246	43.6	228	47.7
	Ratio	0.615	0.637	--	0.618	--	0.609	--	0.545	--	0.544	--
29	BOD	276	207	25.0	167	39.5	140	49.3	111	59.8	119	56.9
	COD	443	343	22.6	295	33.4	269	39.3	216	51.3	223	49.7
	Ratio	0.623	0.603	--	0.566	--	0.520	--	0.514	--	0.534	--
March 1	BOD	264	195	26.1	161	39.0	161	39.0	126	52.3	123	53.4
	COD	439	325	26.0	278	36.7	287	34.6	241	45.1	231	47.4
	Ratio	0.601	0.600	--	0.579	--	0.561	--	0.523	--	0.532	--
2	BOD	233	--	--	97	58.4	--	--	123	47.2	74	68.3
	COD	379	--	--	192	49.4	--	--	224	40.9	164	56.7
	Ratio	0.615	--	--	0.505	--	--	--	0.549	--	0.451	--
3	BOD	237	--	--	87	63.3	--	--	137	42.2	122	48.5
	COD	377	--	--	189	49.9	--	--	240	36.3	210	44.3
	Ratio	0.629	--	--	0.460	--	--	--	0.571	--	0.581	--
5	BOD	105	--	--	55	47.6	--	--	37	64.8	31	70.5
	COD	210	--	--	141	32.9	--	--	107	49.1	98	53.3
	Ratio	0.500	--	--	0.390	--	--	--	0.346	--	0.316	--
6	BOD	163	--	--	93	43.0	--	--	99	39.3	45	72.4
	COD	300	--	--	158	47.3	--	--	190	36.7	124	58.7
	Ratio	0.543	--	--	0.589	--	--	--	0.521	--	0.363	--
7	BOD	162	--	--	89	45.1	--	--	43	73.5	49	69.8
	COD	283	--	--	182	35.7	--	--	110	61.1	125	55.8
	Ratio	0.572	--	--	0.489	--	--	--	0.391	--	0.392	--

Table A-32, Relationship of Performance to Depth at 15.9 GPM, Cont'd.

Date March 1956	Determin-ation	Influent	10.5' ppm	Depth %R*	21' ppm	Depth %R*	31.5' ppm	Depth %R*	42' ppm	Depth %R*	Final ppm	Influent %R*
8	BOD	195	--	--	143	26.7	--	--	83	57.4	66	66.2
	COD	315	--	--	241	23.5	--	--	161	48.9	127	59.7
	Ratio	0.619	--	--	0.593	--	--	--	0.516	--	0.520	--
9	BOD	190	--	--	119	37.4	--	--	57	70.0	74	61.1
	COD	287	--	--	176	38.7	--	--	133	53.7	98	65.9
	Ratio	0.662	--	--	0.676	--	--	--	0.429	--	0.755	--
10	BOD	189	--	--	132	30.2	--	--	73	61.4	61	67.7
	COD	339	--	--	247	27.1	--	--	166	51.0	163	51.9
	Ratio	0.558	--	--	0.534	--	--	--	0.440	--	0.374	--
12	BOD	122	--	--	49	59.8	--	--	39	68.0	31	74.6
	COD	237	--	--	118	50.2	--	--	101	57.4	91	61.6
	Ratio	0.515	--	--	0.415	--	--	--	0.386	--	0.341	--
13	BOD	233	--	--	121	48.1	--	--	76	67.4	65	72.1
	COD	391	--	--	232	40.7	--	--	182	53.5	158	59.6
	Ratio	0.596	--	--	0.522	--	--	--	0.418	--	0.411	--
14	BOD	190	--	--	111	41.6	--	--	46	75.8	45	76.3
	COD	336	--	--	224	33.3	--	--	143	57.5	142	57.7
	Ratio	0.565	--	--	0.496	--	--	--	0.322	--	0.317	--
Mean Values	BOD	212	--	--	195	--	--	--	--	54.8	--	60.6
	COD	352	--	--	--	--	--	--	--	--	--	--
	Ratio	0.602	--	--	--	--	--	--	--	--	--	--

* Percent Removal

**Tower Samples beginning with February 18 were laboratory settled prior to analysis

Table A-33

Dowpac HCS Tower Performance

Relationship of Performance to Depth at a Hydraulic Rate of 16 GPM Direct (Nominal) Plus 16 GPM Recirculation**

Date March 1956	Chemical Oxygen Demand - parts per million					Performance - Percent Removal				
	Influent CD	21'Depth Settled CSS	42'Depth Settled CAS	42'Depth Unsettled CA	Final Effluent CB	21'Depth Settled CD & CSS	42'Depth Settled CD & CSS	42'Depth Unsettled CD & CA	Final Effluent CD & CB	By Tank Only CA & CB
20	476	378	193	206	248	20.6	59.5	56.7	47.9	---
21	387	260	185	173	166	32.8	52.2	55.3	57.1	4.1
22	364	271	177	207	171	25.6	51.4	43.1	53.0	17.4
23	370	209	176	196	213	43.5	52.4	47.0	42.4	---
24*	417	302	307	371	240	27.6	26.4	11.0	42.5	35.3
27	520	352	282	289	282	32.3	45.8	44.4	45.8	2.4
28	317	195	192	186	184	38.5	39.4	41.3	42.0	1.1
29	421	231	193	295	168	45.1	54.2	29.9	60.1	43.1
30	339	196	196	258	165	42.2	42.2	23.9	51.3	36.1
31*	343	205	192	216	173	40.2	44.0	37.0	49.6	19.9
April										
3	535	323	254	340	243	39.6	52.5	36.5	54.6	28.5
4	378	188	193	240	161	50.3	49.0	36.5	57.4	32.9
5	323	151	127	199	166	53.3	60.7	38.4	48.6	16.6
6	354	178	176	215	142	49.7	50.3	39.3	59.9	34.0
7	410	245	224	268	209	40.3	45.4	34.6	49.0	22.0
				Mean Removals		38.8	48.4	38.3	50.7	22.6

* Sampling only interrupted for 48 hours

**Recirculant - unsettled tower effluent

Note: Please refer to Figure 9 in text for code to sampling stations.

Table A-34

Dowpac HCS Pilot Plant

Relationship of Performance to Depth at a Hydraulic Rate of 8.0 GPM

Date April 1956	Determination	Biochemical and Chemical Oxygen Demand - ppm					Performance - Percent Removal					
		Influent CD	21'Depth Settled CSS	42'Depth Settled CAS	42'Depth Unsettled CA	Final Effluent CB	21'Depth Settled CD & CSS	42'Depth Settled CD & CAS	Tower Alone CD & CA	Tower & Tank CD & CB	By Tank only CA & CB	Lab Settling only CA & CAS
10	BOD	--	--	--	--	--	--	--	--	--	--	--
	COD	281	138	150	143	126	50.9	46.6	49.1	55.2	11.9	4.9
	Ratio	--	--	--	--	--	--	--	--	--	--	--
11	BOD	217	107	64	--	--	50.7	70.5	--	--	--	--
	COD	337	182	136	151	131	46.0	59.7	55.2	61.1	13.3	9.9
	Ratio	0.644	0.588	0.471	--	--	--	--	--	--	--	--
12	BOD	194	86	49	--	--	55.7	74.8	--	--	--	--
	COD	349	179	107	175	110	48.7	69.4	49.9	68.5	37.2	38.9
	Ratio	0.556	0.480	0.458	--	--	--	--	--	--	--	--
13	BOD	215	114	54	--	--	47.0	74.9	--	--	--	--
	COD	331	237	127	155	99	28.4	61.6	53.2	70.1	36.1	18.1
	Ratio	0.650	0.481	0.425	--	--	--	--	--	--	--	--
14	BOD	181	68	33	--	--	62.4	81.8	--	--	--	--
	COD	302	177	119	145	104	41.4	60.6	52.0	65.6	28.3	17.9
	Ratio	0.599	0.384	0.277	--	--	--	--	--	--	--	--
17	BOD	242	61	40	--	--	74.8	83.5	--	--	--	--
	COD	368	160	92	152	110	56.5	75.0	58.7	70.1	27.6	39.5
	Ratio	0.658	0.381	0.435	--	--	--	--	--	--	--	--
18	BOD	270	126	71	--	--	53.3	73.7	--	--	--	--
	COD	416	229	160	189	163	45.0	61.5	54.6	60.8	13.8	15.4
	Ratio	0.351	0.550	0.444	--	--	--	--	--	--	--	--
19	BOD	275	163	57	--	--	40.7	79.3	--	--	--	--
	COD	430	272	154	176	154	36.8	64.2	59.1	64.2	12.5	12.5
	Ratio	0.640	0.599	0.370	--	--	--	--	--	--	--	--

Note: Please refer to Figure 9 in text for code to sampling stations.

Table A-34, Relationship of Performance to Depth at 8.0 GPM, Cont'd.

Date April 1956	Determin-ation	Biochemical and Chemical Oxygen Demand - ppm Influent CD	21'Depth Settled CSS	42'Depth Settled CAS	42'Depth Unsettled CA	Final Effluent CB	Performance - Percent Removal 21'Depth Settled CD & CSS	42'Depth Settled CD & CAS	Tower Alone CD & CA	Tower & Tank CD & CB	By Tank only CA & CB	Lab Settling only CA & CAS
20	BOD	433	64	110	--	--	85.2	74.6	--	--	--	--
	COD	371	234	157	211	168	36.9	57.7	43.1	54.7	20.4	25.6
	Ratio	1.169	0.274	0.701	--	--	--	--	--	--	--	--
21	BOD	286	125	84	--	--	56.3	70.6	--	--	--	--
	COD	544	205	294	318	93	62.3	46.0	41.6	82.9	70.8	7.6
	Ratio	0.526	0.610	0.286	--	--	--	--	--	--	--	--
24	BOD	288	101	56	--	--	64.9	80.6	--	--	--	--
	COD	538	316	226	333	249	41.3	58.0	38.1	53.7	25.2	32.1
	Ratio	0.535	0.320	0.248	--	--	--	--	--	--	--	--
25	BOD	272	152	60	--	--	44.1	78.0	--	--	--	--
	COD	599	246	166	201	136	58.9	72.3	66.5	77.3	32.3	17.4
	Ratio	0.454	0.618	0.361	--	--	--	--	--	--	--	--
26	BOD	233	91	48	--	--	61.0	79.4	--	--	--	--
	COD	383	185	88	163	115	51.7	77.0	57.5	70.0	29.5	46.0
	Ratio	0.608	0.492	0.545	--	--	--	--	--	--	--	--
27	BOD	165	56	39	--	--	66.1	76.4	--	--	--	--
	COD	232	91	59	64	56	60.8	74.6	72.4	75.9	12.5	78.2
	Ratio	0.711	0.615	0.661	--	--	--	--	--	--	--	--
28	BOD	157	42	28	--	--	73.3	82.2	--	--	--	--
	COD	216	70	28	59	46	67.6	87.0	72.7	78.7	22.0	52.6
	Ratio	0.727	0.600	1.000	--	--	--	--	--	--	--	--

Note: Please refer to Figure 9 in text for code to sampling stations.

Table A-35

Dowpac HCS Pilot Plant

Relationship of Performance to Depth at a Hydraulic Rate of 3.1 GPM

Basis: Biochemical Oxygen Demand

Date June 1956	Influent BOD-ppm	10.5'Depth Settled ppm	10.5'Depth Settled %R*	21'Depth Settled ppm	21'Depth Settled %R*	31.5'Depth Settled ppm	31.5'Depth Settled %R*	42'Depth Settled ppm	42'Depth Settled %R*	42'Depth Unsettled ppm	42'Depth Unsettled %R*
11	247	79.5	67.8	45.3	81.7	42.7	82.7	47.8	80.7	147	40.5
12	239	371	--	32.0	86.6	25.7	89.3	35.8	85.0	63.5	73.4
13	307	370	--	102	66.8	77.3	74.8	36.2	88.2	56.7	81.5
14	300	197	34.3	110	63.3	47.0	84.3	24.6	91.8	58.0	80.7
15	293	139	52.6	83.3	71.6	39.7	86.5	34.8	88.1	59.0	79.9
16	287	38.3	86.7	103	64.1	111	61.3	26.5	90.8	80.8	71.9
17	193	125	35.2	79.3	58.9	60.0	68.9	58.0	70.0	152	21.3
18	147	87.0	40.8	69.7	52.6	71.0	51.7	65.8	55.2	149	--
19	221	148	33.0	83.0	62.5	46.7	78.9	50.0	77.4	113	48.9
20	222	141	36.5	55.0	75.2	36.3	83.7	38.3	82.8	78.7	64.0
21	278	193	30.6	136	51.1	35.5	87.2	31.5	88.7	60.3	78.3
22	299	231	22.8	215	28.1	134	55.2	51.0	83.0	87.5	70.7
23	293	208	29.0	164	44.0	143	51.2	32.8	88.8	51.0	82.6
24	228	198	13.2	160	29.8	75.2	67.0	25.5	88.8	34.3	85.0
25	194	140	27.8	95.3	50.9	25.7	86.8	22.8	88.3	24.5	87.4
26	242	167	31.0	134	44.6	32.4	86.6	27.5	88.6	54.3	77.6
27	227	203	10.6	92.8	59.1	60.7	73.3	41.0	81.9	87.0	61.7
Mean	248	153	36.8	104	58.3	62.6	74.7	38.2	83.4	79.8	69.1**

*Removal

**Excluding June 18

Table A-36

Dowpac HCS Pilot Plant

Tabulation of Biochemical Oxygen Demand Loading and Percent Remaining at Various Depths for Several Hydraulic Rates

Date Feb. 1956	Hydraulic Rate-GPM	10.5 ft. Depth Lb/1000 ft^3/day	10.5 ft. Depth %R*	21 ft. Depth Lb/1000 ft^3/day	21 ft. Depth %R*	31.5 ft. Depth Lb/1000 ft^3/day	31.5 ft. Depth %R*	42 ft. Depth Lb/1000 ft^3/day	42 ft. Depth %R*
18	15.9	680	86.5	340	76.4	227	68.4	170	61.0
19	"	173	88.2	86.6	71.0	57.7	63.4	43.3	58.1
20	"	307	78.8	154	58.8	102	44.8	76.8	43.0
21	"	548	90.8	274	78.6	183	68.0	137	60.2
22	"	444	88.7	222	81.6	148	73.2	111	63.2
23	"	552	84.5	276	69.4	184	69.7	138	56.6
24	"	552	88.7	276	78.0	184	59.7	138	47.7
25	"	436	79.8	218	67.4	145	63.9	109	49.3
26	"	317	71.2	158	67.6	106	55.3	79.2	44.1
27	"	218	73.5	109	51.3	72.6	41.9	54.5	30.8
28	"	500	82.5	250	67.5	167	62.3	125	50.0
29	"	516	75.0	258	60.5	172	50.7	129	40.2
Mar 1	"	492	73.9	246	61.0	164	61.0	123	47.7
2	"	--	--	218	41.6	--	--	109	52.8
3	"	--	--	220	36.7	--	--	110	57.8
5	"	--	--	97.8	52.4	--	--	48.9	35.2
6	"	--	--	152	57.0	--	--	75.9	60.7
7	"	--	--	151	54.9	--	--	75.4	26.5
8	"	--	--	182	73.3	--	--	90.8	42.6
9	"	--	--	177	62.6	--	--	88.5	30.0
10	"	--	--	176	69.8	--	--	88.0	38.6
12	"	--	--	114	40.2	--	--	56.8	32.0
13	"	--	--	218	51.9	--	--	109	32.6
14	"	--	--	177	58.4	--	--	88.5	24.2
Apr 11	8.0	204	--	102	49.3	68.0	--	51.0	29.5
12	"	182	--	91.2	44.3	60.8	--	45.6	25.2
13	"	202	--	101	53.0	67.3	--	50.5	25.1
14	"	170	--	85.0	37.6	56.7	--	42.5	18.2
17	"	227	--	114	25.2	75.7	--	56.8	16.5
18	"	254	--	127	46.7	84.5	--	63.4	26.3

* Remaining

Table A-36, Tabulation of BOD Loading and Performance, Cont'd.

Date Apr. 1956	Hydraulic Rate-GPM	10.5 ft. Depth Lb/1000 ft^3/day	%R*	21 ft. Depth Lb/1000 ft^3/day	%R*	31.5 ft. Depth Lb/1000 ft^3/day	%R*	42 ft. Depth Lb/1000 ft^3/day	%R*
19	8.0	258	--	129	59.3	86.1	--	64.6	20.7
20	"	408	--	204	14.8	136	--	102	25.4
21	"	269	--	134	43.7	89.6	--	67.2	29.4
24	"	271	--	135	35.1	90.2	--	67.7	19.4
25	"	256	--	128	55.9	85.2	--	63.9	22.0
26	"	219	--	109	39.0	72.9	--	54.7	20.6
27	"	155	--	77.6	33.9	51.7	--	38.8	23.6
28	"	148	--	73.8	26.7	49.2	--	36.9	17.8
June									
11	3.1	90.0	32.2	45.0	18.3	30.0	17.3	22.5	19.3
12	"	86.8	--	43.4	13.4	28.9	10.7	21.7	15.0
13	"	112	--	55.8	33.2	37.2	25.2	27.9	11.8
14	"	109	65.7	54.6	36.7	36.4	15.7	27.3	8.2
15	"	107	47.4	53.4	28.4	35.6	13.5	26.7	11.9
16	"	104	13.3	52.2	35.9	34.8	38.7	26.1	9.2
17	"	70.4	64.8	35.2	41.1	23.5	31.1	17.6	30.0
18	"	53.6	59.2	26.8	47.4	17.9	48.3	13.4	44.8
19	"	80.4	67.0	40.2	37.5	26.8	21.1	20.1	22.6
20	"	80.8	63.5	40.4	24.8	26.9	16.3	20.2	17.2
21	"	101	69.4	50.6	48.9	33.7	12.8	25.3	11.3
22	"	109	77.2	54.4	71.9	36.3	44.8	27.2	17.0
23	"	107	71.0	53.4	56.0	35.6	48.8	26.7	11.2
24	"	82.8	86.8	41.4	70.2	27.6	33.0	20.7	11.2
25	"	69.6	72.2	34.8	49.1	23.2	13.2	17.4	11.7
26	"	88.0	69.0	44.0	55.4	29.3	13.4	22.0	11.4
27	"	82.8	89.4	41.4	40.9	27.6	26.7	20.7	18.1

*Remaining

Table A-37

Suspended and Volatile Suspended Solids Concentrations

			Concentrations - Parts per Million		
Date 1956 Feb.	Determination*	CD Influent	CA Tower Effluent	CAS Settled Tower Effluent	CB Final Tank Effluent
19	SS	51	79	45	46
	VSS	43	73	43	40
20	SS	66	82	53	37
	VSS	58	77	44	36
21	SS	96	94	72	42
	VSS	77	84	66	40
22	SS	63	64	49	44
	VSS	59	60	46	43
23	SS	74	55	43	29
	VSS	70	55	42	29
24	SS	61	90	51	43
	VSS	59	85	44	41
25	SS	124	79	57	60
	VSS	77	57	40	42
26	SS	59	103	33	32
	VSS	47	90	32	30
27	SS	44	39	25	26
	VSS	38	29	21	22
28	SS	65	61	32	23
	VSS	63	57	32	23
29	SS	83	70	60	47
	VSS	69	61	51	36
March 1	SS	75	124	52	42
	VSS	67	124	52	42
2	SS	89	98	51	38
	VSS	58	62	39	31
3	SS	63	66	39	43
	VSS	51	54	38	40
5	SS	56	141	41	21
	VSS	52	118	39	21

VSS-Volatile Suspended Solids
SS-Suspended Solids
*4-hour Composites

Table A-37, Suspended and Volatile Suspended Solids Concentrations - Cont'd.

			Concentrations - Parts per Million		
Date 1956 Mar.	Determination*	CD Influent	CA Tower Effluent	CAS Settled Tower Effluent	CB Final Tank Effluent
6	SS	69	53	38	20
	VSS	55	48	38	20
7	SS	83	32	26	21
	VSS	62	30	26	19
8	SS	69	45	35	36
	VSS	67	43	34	36
9	SS	68	91	49	30
	VSS	55	79	40	25
10	SS	66	59	41	36
	VSS	57	51	34	30
12	SS	71	66	38	25
	VSS	57	60	30	22
13	SS	51	65	52	42
	VSS	51	64	49	41
14	SS	64	78	54	40
	VSS	49	57	33	33
22	SS	77	105	67	57
	VSS	68	94	63	57
23	SS	107	176	73	65
	VSS	89	149	54	56
24	SS	65	182	126	66
	VSS	56	147	104	54
27	SS	86	89	75	61
	VSS	74	81	67	52
28	SS	89	90	92	76
	VSS	65	81	83	65
29	SS	90	173	84	74
	VSS	85	145	70	61
30	SS	94	111	86	67
	VSS	81	87	69	54

*4-hour composites
SS-Suspended Solids
VSS-Volatile Suspended Solids

Table A-37, Suspended and Volatile Suspended Solids Concentrations Cont'd.

		Concentrations - Parts per Million			
Date 1956 Mar.	Determination*	CD Influent	CA Tower Effluent	CAS Settled Tower Effluent	CB Final Tank Effluent
31	SS	69	102	82	61
	VSS	57	90	71	53
April 4	SS	102	147	83	67
	VSS	95	125	75	65
5	SS	61	90	67	54
	VSS	53	79	61	54
6	SS	79	91	70	56
	VSS	74	81	62	53
7	SS	54	100	64	52
	VSS	54	93	64	52
11	SS	91	80	69	55
	VSS	77	73	57	53
12	SS	92	118	41	34
	VSS	80	108	32	27
13	SS	86	76	47	37
	VSS	86	76	47	37
14	SS	60	50	50	33
	VSS	51	46	47	29
17	SS	86	75	36	31
	VSS	60	57	29	22
18	SS	68	68	48	39
	VSS	45	54	37	37
19	SS	94	77	56	41
	VSS	82	65	49	41
20	SS	63	69	51	29
	VSS	58	59	49	26
21	SS	106	85	58	39
	VSS	88	73	55	39
24	SS	109	74	53	39
	VSS	96	67	46	31

*-4-hour composites
SS-Suspended Solids
VSS-Volatile Suspended Solids

Table A-37, Suspended and Volatile Suspended Solids Concentrations Cont'd.

			Concentrations - Parts per Million		
Date 1956 Apr.	Determination*	CD Influent	CA Tower Effluent	CAS Settled Tower Effluent	CB Final Tank Effluent
25	SS	110	105	57	42
	VSS	96	91	49	38
26	SS	110	68	51	41
	VSS	91	55	51	40
27	SS	182	82	31	23
	VSS	87	36	23	23
28	SS	108	62	40	27
	VSS	72	43	26	23
June	SS	59	405	68	--
11	VSS	54	297	56	--
12	SS	90	122	56	--
	VSS	79	93	46	--
13	SS	98	112	48	--
	VSS	98	87	38	--
14	SS	101	101	39	--
	VSS	100	85	39	--
15	SS	72	110	49	--
	VSS	72	95	49	--
16	SS	82	174	28	--
	VSS	82	139	28	--
17	SS	53	361	93	--
	VSS	49	261	52	--
18	SS	66	459	115	--
	VSS	53	268	86	--
19	SS	80	296	91	--
	VSS	76	224	70	--
20	SS	72	201	70	--
	VSS	72	137	50	--
21	SS	65	190	78	--
	VSS	65	149	63	--

*4-hour composites
SS-Suspended Solids
VSS-Volatile Suspended Solids

Table A-37, Suspended and Volatile Suspended Solids Concentrations Cont'd.

		Concentrations - Parts per Million			
Date 1956 June	Determination*	CD Influent	CA Tower Effluent	CAS Settled Tower Effluent	CB Final Tank Effluent
22	SS	80	144	60	--
	VSS	80	116	56	--
23	SS	85	102	41	--
	VSS	81	82	40	--
24	SS	74	63	20	--
	VSS	74	63	20	--
25	SS	57	30	26	--
	VSS	44	30	22	--
26	SS	67	90	42	--
	VSS	58	76	40	--
27	SS	74	172	65	--
	VSS	61	127	49	--

*4-hour composites
SS-Suspended Solids
VSS-Volatile Suspended Solids

Summary:

Influent - CD	Mean	High	Low
Suspended Solids	79	182	44
Volatile Suspended Solids	68	100	38

Table A-38

Secondary Tank Solids Reduction Compared With Reduction by Laboratory Settling

Date 1956 Feb.	Determin-* ation	Solids Concentration - Parts per million			Percent Reduction	
		Tower Effluent	Tower Effluent minus Final Effluent	Tower Effluent minus Settled Tower Effluent	By Final Tank	By Lab Settling
19	SS	79	33	34	41.8	43.0
	VSS	73	33	30	45.2	41.1
20	SS	82	45	29	54.9	35.4
	VSS	77	41	33	53.2	42.9
21	SS	94	52	22	55.3	23.4
	VSS	84	44	18	52.4	21.4
22	SS	64	20	15	31.3	23.4
	VSS	60	17	14	28.3	23.3
23	SS	55	26	12	47.3	21.8
	VSS	55	26	13	47.3	23.6
24	SS	90	47	39	52.2	43.3
	VSS	85	44	41	51.8	48.2
25	SS	79	19	22	24.1	27.8
	VSS	57	15	17	26.3	29.8
26	SS	103	71	70	68.9	68.0
	VSS	90	60	58	66.7	64.4
27	SS	39	13	14	33.3	35.9
	VSS	29	7	8	24.1	27.6
28	SS	61	38	29	62.3	47.5
	VSS	57	34	25	59.6	43.9
29	SS	70	23	10	32.9	14.3
	VSS	61	25	10	41.0	16.4

* 4-hour composites
SS-Suspended Solids
VSS-Volatile Suspended Solids

Table A-38

Secondary Tank Solids Reduction Compared With Reduction by Laboratory Settling, Cont'd.

		Solids Concentration - Parts per million			Percent Reduction	
Date 1956 Mar.	Determin-* ation	Tower Effluent	Tower Effluent minus Final Effluent	Tower Effluent minus Settled Tower Effluent	By Final Tank	By Lab Settling
1	SS	124	82	72	66.1	58.1
	VSS	124	82	72	66.1	58.1
2	SS	98	60	47	61.2	48.0
	VSS	62	31	23	50.0	37.1
3	SS	66	23	27	34.8	40.9
	VSS	54	14	16	25.9	29.6
5	SS	141	120	100	85.1	70.9
	VSS	118	97	79	82.2	66.9
6	SS	53	33	15	62.3	28.3
	VSS	48	28	10	58.3	20.8
7	SS	32	11	6	34.4	18.8
	VSS	30	11	4	36.7	13.3
8	SS	45	9	10	20.0	22.2
	VSS	43	7	9	16.3	20.9
9	SS	91	61	42	67.0	46.2
	VSS	79	54	39	68.4	49.4
10	SS	59	23	18	39.0	30.5
	VSS	51	21	17	41.2	33.3
12	SS	66	41	28	62.1	42.4
	VSS	60	38	30	63.3	50.0
13	SS	65	23	13	35.4	20.0
	VSS	64	23	15	35.9	23.4

* 4-hour composites
SS-Suspended Solids
VSS-Volatile Suspended Solids

Table A-38

Secondary Tank Solids Reduction Compared with Reduction by Laboratory Settling, Cont'd.

Date 1956 Mar.	Determin-* ation	Solids Concentration - Parts per Million Tower Effluent	Tower Effluent minus Final Effluent	Tower Effluent minus Settled Tower Effluent	Percent Reduction By Final Tank	By Lab Settling
14	SS	78	38	24	48.7	30.8
	VSS	57	24	24	42.1	42.1
22	SS	105	48	38	45.7	36.2
	VSS	94	37	31	39.4	33.0
23	SS	176	111	103	63.1	58.5
	VSS	149	93	95	62.4	63.8
24	SS	182	116	56	63.7	30.8
	VSS	147	93	43	63.3	29.3
27	SS	89	28	14	31.5	15.7
	VSS	81	29	14	35.8	17.3
28	SS	90	14	+ 2	15.6	0
	VSS	81	16	+ 2	19.8	0
29	SS	173	99	89	57.2	51.4
	VSS	145	84	75	57.9	51.7
30	SS	111	44	25	39.6	22.5
	VSS	87	33	18	37.9	20.7
31	SS	102	41	20	40.2	19.6
	VSS	90	37	19	41.1	21.1
Apr. 4	SS	147	80	64	54.4	43.5
	VSS	125	60	50	48.0	40.0
5	SS	90	36	23	40.0	25.6
	VSS	79	25	18	31.6	22.8

* 4-hour composites
SS-Suspended Solids
VSS-Volatile Suspended Solids

Table A-38

Secondary Tank Solids Reduction Compared with Reduction by Laboratory Settling, Cont'd.

Date 1956 Apr.	Determin-* ation	Solids Concentration - Parts per Million: Tower Effluent	Solids Concentration - Parts per Million: Tower Effluent minus Final Effluent	Solids Concentration - Parts per Million: Tower Effluent minus Settled Tower Effluent	Percent Reduction By Final Tank	Percent Reduction By Lab Settling
6	SS	91	35	21	38.5	23.1
	VSS	81	28	19	34.6	23.5
7	SS	100	48	36	48.0	36.0
	VSS	93	41	29	44.1	31.2
11	SS	80	25	11	31.3	13.8
	VSS	73	20	16	27.4	21.9
12	SS	118	84	77	71.2	65.3
	VSS	108	81	76	75.0	70.4
13	SS	76	39	29	51.3	38.2
	VSS	76	39	29	51.3	38.2
14	SS	50	17	0	34.0	0
	VSS	46	17	+ 1	37.0	0
17	SS	75	44	39	58.7	52.0
	VSS	57	35	28	61.4	49.1
18	SS	68	29	20	42.6	29.4
	VSS	54	17	17	31.5	31.5
19	SS	77	36	21	46.8	27.3
	VSS	65	24	16	36.9	24.6
20	SS	69	40	18	58.0	26.1
	VSS	59	33	10	55.9	16.9
21	SS	85	46	27	54.1	31.8
	VSS	73	34	18	46.6	24.7

* 4-hour composites
SS-Suspended Solids
VSS-Volatile Suspended Solids

Table A-38

Secondary Tank Solids Reduction Compared with Reduction by Laboratory Settling, Cont'd.

		Solids Concentration - Parts per Million			Percent Reduction	
Date 1956 Apr.	Determin-* ation	Tower Effluent	Tower Effluent Minus Final Effluent	Tower Effluent Minus Settled Tower Effluent	By Final Tank	By Lab Settling
24	SS	74	35	21	47.3	28.4
	VSS	67	36	21	53.7	31.3
25	SS	105	63	48	60.0	45.7
	VSS	91	53	42	58.2	46.2
26	SS	68	27	17	39.7	25.0
	VSS	55	15	4	27.3	7.27
27	SS	82	59	51	72.0	62.2
	VSS	36	13	13	36.1	36.1
28	SS	62	35	22	56.5	35.5
	VSS	43	20	17	46.5	39.5
Means	SS				48.6	34.4
	VSS				45.8	33.1

* 4-hour composites
SS-Suspended Solids
VSS-Volatile Suspended Solids

Table A-39

Solids Reduction by Laboratory Settling

Date 1956 June	Determination*	Concentrations - ppm Tower Effluent	Concentrations - ppm Tower Effluent Minus Settled Tower Effluent	Percent Removal by Lab Settling
11	SS	405	337	83.2
	VSS	297	241	81.1
12	SS	122	66	54.1
	VSS	93	47	50.5
13	SS	112	64	57.1
	VSS	87	49	56.3
14	SS	101	62	61.4
	VSS	85	46	54.1
15	SS	110	61	55.5
	VSS	95	46	48.4
16	SS	174	146	83.9
	VSS	139	111	79.9
17	SS	361	268	74.2
	VSS	261	209	80.1
18	SS	459	344	74.9
	VSS	268	182	67.9
19	SS	296	205	69.3
	VSS	224	154	68.8
20	SS	201	131	65.2
	VSS	137	87	63.5
21	SS	190	112	58.9
	VSS	149	86	57.7
22	SS	144	84	58.3
	VSS	116	60	51.7
23	SS	102	61	59.8
	VSS	82	42	51.2
24	SS	63	43	71.7
	VSS	63	43	71.7
25	SS	30	4	13.3
	VSS	30	8	26.7

VSS-Volatile Suspended Solids
SS-Suspended Solids
* 4-hour composites

Table A-39, Solids Reduction by Laboratory Settling, Cont'd.

Date 1956 June	Determination*	Concentrations - ppm Tower Effluent	Concentrations - ppm Tower Effluent Minus Settled Tower Effluent	Percent Removal By Lab Settling
26	SS	90	48	53.3
	VSS	76	36	47.4
27	SS	172	107	62.2
	VSS	127	78	61.4
Means	SS	184	126	62.1
	VSS	137	89.7	59.9

* 4-hour composites
SS-Suspended Solids
VSS-Volatile Suspended Solids

Table A-40

Suspended Solids Removal Efficiency of the Final Tank Compared with that of Laboratory Settling

Period and Hydraulic Conditions	Mean Suspended Solids-Percent Removal In Tank Alone	Mean Suspended Solids-Percent Removal By Lab Settling
15.9 GPM Feb.17-Mar.14	48.7	36.6
16 GPM Direct plus 16 GPM recirculation around tower only Mar.20-Apr.8	44.8	30.2
1:1 Recirculation Mar.20-Apr.8	44.8	30.2
8 GPM Apr.10-29	51.7	34.3
3.1 GPM June 11-27	Not Used	62.1

Table A-41

Dowpac HCS Pilot Plant Study - Air and Sewage Temperatures

Date	Air Temperatures*°F. High	Low	Mean	Tower - °F. Influent	Effluent
Jan. 13	38	17	27.5	--	--
14	37	12	24.5	--	--
15	30	17	22.5	--	--
16	32	24	28.0	--	--
17	32	14	23.0	--	--
18	32	19	25.5	--	--
19	30	23	26.5	--	--
20	30	23	26.5	--	--
21	29	20	24.5	--	--
22	22	6	14.0	--	--
23	26	2	14.0	--	--
24	26	3	14.5	--	--
25	27	10	18.5	--	--
26	34	3	18.5	--	--
27	33	9	21.0	--	--
28	35	18	26.5	--	--
29	37	25	31.0	--	--
30	28	18	23.0	--	--
31	27	14	20.5	59	56
Feb. 1	26	7	16.5	59	57
2	31	22	26.5	60	57
3	32	6	19.0	59	57
4	40	8	24.0	57	56
5	35	16	25.5	56	54
6	34	20	27.0	59	56
7	35	30	32.5	59	58
8	42	26	34.0	58	57
9	38	31	34.5	58	56
10	36	24	30.0	58	56
11	29	24	26.5	56	54
12	32	25	28.5	54	52
13	35	24	29.5	58	56
14	44	31	37.5	58	56
15	31	20	25.5	58	55
16	29	14	21.5	57	55
17	34	23	28.5	57	55
18	33	20	26.5	54	51
19	42	11	26.5	53	48
20	31	15	23	56	50
21	24	10	17	55	51
22	26	10	18	55	50
23	33	5	19	57	53
24	43	21	32	55	52
25	45	26	35.5	52	47
26	41	16	28.5	51	48
27	32	20	26.0	52	48
28	28	9	18.5	54	48
29	34	14	24		

Table A-41, Dowpac HCS Pilot Plant Study

Air and Sewage Temperatures, Cont'd.

Date	Air Temperatures*°F. High	Low	Mean	Tower - °F. Influent	Effluent
Feb. 29	34	14	24		
Mar. 1	50	27	38.5	55	51
2	44	33	38.5	51	49
3	42	28	35	51	49
4	46	23	34.5	49	47
5	46	35	40.5	48	46
6	46	37	41.5	51	49
7	41	29	35	51	47
8	31	20	25.5	50	44
9	42	16	29	51	45
10	42	26	34	51	47
11	49	29	39	50	46
12	30	23	26.5	48	44
13	37	18	27.5	50	46
14	34	26	30	55	49
15	35	19	27	56	47
16	34	21	27.5	56	47
17	34	21	27.5	56	50
18	31	22	26.5	55	49
19	35	14	24.5	52	48
20	41	19	30	53	48
21	46	25	35.5	56	51
22	44	34	39	57	52
23	35	29	32	57	54
24	31	4	17.5	55	51
25	36	12	24	54	48
26	47	26	36.5	53	49
27	42	31	36.5	55	51
28	34	29	31.5	55	48
29	35	30	32.5	56	49
30	37	25	31.0	56	51
31	45	22	33.5	56	51
Apr. 1	55	31	43	55	51
2	73	45	59	54	51
3	77	58	67.5	55	54
4	72	41	56.5	58	56
5	65	35	50.0	56	54
6	70	47	58.5	57	54
7	59	31	45.0	58	57
8	40	31	35.5	54	52
9	51	30	40.5	55	52
10	51	31	41.0	55	47
11	59	28	43.5	--	--
12	62	33	47.5	58	55
13	54	29	41.5	59	53
14	67	37	52	59	51
15	57	36	46.5	58	55

Table A-41, Dowpac HCS Pilot Plant Study

Air And Sewage Temperatures, Cont'd.

Date	Air Temperatures*°F. High	Low	Mean	Tower - °F Influent	Effluent
Apr. 15	57	36	46.5		
16	41	34	37.5	56	51
17	40	32	36	58	54
18	46	30	38	58	51
19	50	27	38.5	58	51
20	46	23	34.5	59	52
21	55	37	46	58	50
22	48	33	40.5	58	51
23	45	25	35	56	52
24	48	32	40	59	54
25	50	34	42	60	55
26	59	39	49	60	55
27	76	45	60.5	60	56
28	74	40	57	60	59
29	52	36	44	57	53

Date	Air Temperatures - °F. High	Low	Mean	Waste Temperature°F. Primary Influent**
June				
11	93	62	78	65
12	95	71	83	66
13	94	69	82	66
14	90	70	80	66
15	88	71	80	66
16	84	69	77	66
17	84	67	76	66
18	76	68	72	67
19	81	55	68	67
20	86	65	76	67
21	89	69	79	67
22	85	68	77	67
23	88	72	80	68
24	87	63	75	66
25	75	54	65	66
26	84	58	71	68
27	78	61	70	68
28	73	54	64	66

* From: City of Battle Creek, Flood Warning Station
222 Cliff Street, Battle Creek, Michigan

**Tower influent temperatures not available, but do not vary by more than 1° from primary influent temperature.

Table A-42

Sewage Treatment Plant - Battle Creek, Michigan

Selected Information Obtained from Monthly Summaries of Plant Operation - January Through June, 1956

Month - 1956		January	February	March	April	May	June
Population Served - Total		52,042	51,803	51,949	52,009	52,113	52,190
Average Daily Flow - Million Gallons Per Day		7.33	7.69	8.98	8.67	10.22	8.51
Per Capita Rate - Gallons Per Capita Per Day		142	148	173	167	197	163
Influent Characteristics:	5-day B.O.D.-total pounds	585,600	579,500	579,400	588,000	516,200	557,400
	5-day B.O.D.-lb/capita/day	0.36	0.39	0.36	0.38	0.32	0.36
	Dry suspended solids-pounds/day	12,900	15,800	16,200	13,000	15,800	15,000
	Dry Volatile susp. solids-pounds/day	10,900	12,600	13,200	10,400	11,900	12,600
Effluent Characteristics:	5-day B.O.D. - total pounds	465,000	422,900	486,700	479,400	284,000	356,700
	5-day B.O.D. - lb/capita/day	0.29	0.28	0.30	0.31	0.18	0.23
	Dry suspended solids-pounds/day	5,500	6,900	8,100	6,750	6,300	5,500
	Dry Volatile susp. solids-pounds/day	4,600	5,500	6,500	5,400	4,400	4,600
Supernatant Characteristics:	Volume-total gallons	675,000	-------	666,600	517,100	454,400	413,000
	Dry Solids - total pounds	73,500	-------	55,800	25,800	38,000	18,200
	Dry Volatile Solids-total pounds	46,900	-------	34,900	15,400	23,000	11,400
Performance Characteristics*	5-day B.O.D.-Percent Removal	22.0	21.8	21.9	18.6	35.5	36.6
	Suspended Solids-Percent Removal	55.7	55.3	48.9	51.7	58.4	62.0
*Performance Characteristics as calculated from above average monthly data are:							
	5-day B.O.D.-Percent Removal	20.6	27.0	16.0	18.5	45.0	36.0
	Suspended Solids-Percent Removal	57.3	56.3	50.0	48.1	60.1	63.3